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Effects of Species and Standing Litter on Selection and Utilization in Rough Fescue Grasslands.

By

Darlene M. Moisey ©

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of Master of Science

in

Rangeland and Wildlife Resources

Department of Agricultural, Food and Nutritional Science

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled **Effects of Species and Standing Litter on Selection and Utilization in Rough Fescue Grasslands**, submitted by Darlene M. Moisey in partial fulfillment of the requirements for the degree of Master of Science in Rangeland and Wildlife Resources.

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April 8, 2003

Abstract

During early grazing rough fescue is sensitive to severe defoliation. Two studies determined if cattle preference for rough fescue was affected by season of use or standing litter. The first study determined that of four grasses, rough fescue and Kentucky bluegrass were the most preferred in the critical spring grazing period. Kentucky bluegrass was preferred when grazing fall pastures. Smooth brome and Parry oat grass were generally avoided when grazing spring or fall pastures. The second study determined that spring grazed rough fescue plants subjected to four levels of standing litter removal the preceding fall were selected similarly after six days. Re-selection of plants was not affected by litter removal. Rough fescue plant utilization increased as litter removal treatment became increasingly severe. By the end of the six-day trial 48% of plants were re-selected and those with the most severe litter removal treatment had 95% of the current growth removed.

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1 Introduction

Foothills fescue grasslands are an important natural resource that provide habitat for wildlife, unique recreational opportunities, and year-round foraging opportunities for range cattle (Willms et al. 1985, Willms et al. 1996), while simultaneously fulfilling important regional hydrological functions (Naeth et al. 1991). The ability of fescue grasslands to consistently provide products and perform important environmental functions depends on their ecological health (National Research Council 1994). Moreover, range managers must choose appropriate tools and techniques to improve or maintain rangeland in a healthy, productive state.

Range health is an evolving notion that considers, in part, the composition, ground cover, vertical structure, and hydrologic function of the plant community. Plant community composition is of primary interest in this study.

Rough fescue (*Festuca campestris* Rydb.) is the dominant (Moss and Campbell 1947, Looman 1969) and most productive (Willms et al. 1985) plant species within foothills fescue grasslands. Many studies show that rough fescue growth and subsequent survival is sensitive to the season, severity and frequency of defoliation, (Johnston 1961, McLean and Wikeem 1985, Willms et al. 1985, Willms 1991). Ellison (1960), Looman (1969) and Willms et al. (1996) found that grazing pressure impacts the composition of these plant communities primarily by reducing the abundance of rough fescue, and giving competitive advantage to ungrazed or grazing resistant species (Ellison 1960). Heavily grazed native fescue grasslands, in turn, are subject to invasion by aggressive, introduced plants (Willms et al. 1985). The Society for Range Management (1974) defined invasive plants (i.e. invaders) as plant species absent in undisturbed portions of the original vegetation of a specific range site, which subsequently invade and increase following disturbance, including continued heavy grazing. Species such as Kentucky bluegrass (*Poa pratensis,* L.), smooth brome (*Bromus inermis, Leyss.)*, and timothy (*Phleum pratense*, L.) have been documented as invaders in fescue grasslands, especially on moister sites (Willms 1988). Even native range in good or excellent condition often has small areas invaded to varying degrees. Invaded grasslands generally are considered to be in reduced condition (Wroe et al. 1988).

Rangeland health and productivity are often closely associated. To sustain long-term productivity, managers must consider range health, of which species composition is an important component. Invasive plants such as Kentucky bluegrass are a threat to the long-term sustainability of fescue grasslands by displacing native species. Kentucky bluegrass dominated communities are less productive when soil moisture is limited and suffer greater weathering losses than their native, near-climax counterparts (Willms et al. 1996). Invaded grasslands also have reduced native species diversity (Adams 2001) and are less resistant to drought conditions compared with native dominated communities (Willms et al. 1996).

Ranchers have recognized both the potential yield losses, and the potential of these invasive grasses to produce a flush of high quality growth in the spring. For some ranches, grazing during the sensitive growing period has been unavoidable. Skim grazing was implemented in an attempt to capitalize on the early growth of invasive plants while reducing the negative impact of grazing during this time (Adams 2001, Thomas 2001). Under this system, managers applied a light spring graze, then returned cattle in late fall or after plant senescence to graze the remaining forage. Inherent to the successful use of skim grazing is the assumption that cattle prefer to utilize rapidly growing invasive grasses during spring, while minimizing the use of native species at that time.

This research project evaluated plant selection and utilization within fescue grasslands in two main experiments. Selection and utilization were emphasized because they are two key factors strongly influencing plant survival, species composition, and ultimately, rangeland health (Ellision 1960, Willms et al. 1985, Willms 1988). The first study examined preferences by steers for different native and invasive grass species in a mixed sward (Chapter 3). The second study addressed the impact of standing litter on subsequent selection of rough fescue by cattle (Chapter 4).

1.1 Literature Cited

Adams, B.A. 2001. Regional Range Management Specialist. Southeast Region, Alberta Sustainable Resource Development. Personal Communication.

Ellison, L. 1960. Influence of grazing on plant succession of rangelands. Bot. Review. 26:1-75.

Johnston, A. 1961. Comparison of lightly grazed and ungrazed range in the fescue grassland of southwestern Alberta. Can. J. Plant Sci. 41:615-622.

Looman, J. 1969. The fescue grassland of western Canada. Vegetatio 19:128-145.

McLean, A., and S. Wikeem. 1985. Rough fescue response to season and intensity of defoliation. J. Range Manage. 38:-100-103.

Moss, E.H., and J.A. Campbell. 1947. The fescue grasslands of Alberta. Can. J. Res. Sect. C. Bot. Sci. 25:209-227.

Naeth M.A., A.W. Bailey, D.J. Pluth, D.S. Chanasyk, and R.T. Hardin. 1991. Grazing impacts on litter and soil organic matter in mixed prairie and fescue grassland ecosystems of Alberta. J. Range Manage. 44:7-12.

National Research Council. 1984. Nutrient requirements of beef cattle. Sixth revised edition. National Academy Press. Washington.

Society for Range Management. 1989. A Glossary of Terms Used in Range Management (3rd Ed.). Society for Range Management, Denver, Colo.

Thomas, L. 2001. "Skim" grazing helps get this ranch ready for drought. Canadian Cattlemen. June/July:8-9.

Willms W.D., B.W. Adams, and J.F. Dormaar. 1996. Seasonal changes of herbage biomass on the fescue prairie. J. Range Manage. 49:100-104.

Willms, W.D. 1988. Forage production and utilization in various topographic zones of the fescue grasslands. Can. J. Anim. sci. 68:211-223.

Willms, W.D. 1991. Cutting frequency and cutting height effects on rough fescue and Parry oat grass yields. J. Range Manage. 44:82-86.

Willms, W.D., S. Smoliak, and J.F. Dormaar. 1985. Effects of stocking rate on rough fescue grassland vegetation. J. Range Manage. 38:220-225.

Wroe, R.A., S. Smoliak, B.W. Adams, W.D. Willms, and M.L. Anderson. 1988. Guide to range condition and stocking rates for Alberta grasslands. Publ. of Alberta Forestry, Lands, and Wildlife, Edmonton, Alberta.

2 Literature Review

2.1 *Fescue Prairie*

Johnston (1958) reported that the rough fescue complex in North America (see taxonomy section 2.5.1), was known to occupy areas as far north as the Yukon and south to New Mexico, west into Oregon and east to the western parts of Newfoundland. Within Canada, the largest areas were found in Saskatchewan, British Columbia [1.3 million ha (Stout et al. 1981)], and Alberta [440 thousand ha (Adams et al. 1993)]. Coupland and Brayshaw (1953) reported that in central Saskatchewan the Fescue Association has considerable presence in the Dark Brown soil zone and extended north through the aspen grove region, becoming dominant with penetration of the Black Soil zone. Fescue grasslands were also found in the Cypress Hills region of southern Saskatchewan and Alberta.

There has been considerable evidence that the *Agropyron-Stipa-Carex* associes is a sub-climax of the climax *Festuca-Danthonia* association and that full expression of the later, has not been achieved or even retrogressed by European settlement (Moss 1944). Moss and Campbell (1947) suggested that the rough fescue grasslands preceded forest occupying Black and Dark-Gray soil zones, along with pockets in the Brown soil zone.

Strong and Legget (1992) differentiated two rough fescue range types based on the dominant and co-dominant species. The

Festuca halli (Vassey) Piper - *Stipa curtiseta* A.S. Hitchc. range type was the dominant potential natural community in the northern extent of the fescue prairie of central Alberta, Saskatchewan (Coupland and Brayshaw 1953), and Manitoba (Pavlick and Looman 1984). The *Festuca campestris* Rydb. - *Danthonia parryii* Scribn. range type occupies the foothills of the Rocky Mountains (Pavlick and Looman 1984).

2.1.1 Climate

The general climate of rough fescue prairie is characterized by warm summers (mean 14°C) and cold winters with temperatures that are often affected by warmer chinook winds (Coupland and Brayshaw 1953, Strong and Legget 1992). Mean annual precipitation was reported as 445 mm (Strong and Legget 1992) but is likely more accurate at 520 mm (Strong and Legget 1981), of which 56 to 70% falls from May to September (Strong and Legget 1981, Coupland and Brayshaw 1953, respectively) and about 27% falls as snow.

2.1.2 General Ecology

Within half a century of the expansion of European settlement (i.e. late 1800's), cultivation and overgrazing had reduced America's original grazing capacity by half (Costello 1964). Inconsistent forage supplies, drought, and economic hardship spurred on the development of the concepts of range management and conservation.

Sampson (1919), as discussed by Dyksterhuis (1949), first developed and published the concept of range condition class after 13 years of work. Later, the Society for Range Management (1974) stated that a commonly used definition of range condition was "the present state of vegetation of a range site in relation to the climax (natural potential) plant community for that site". It was an expression of the relative degree to which the kinds, proportions, and amounts of plants in a plant community resemble that of the (assumed) climax plant community for the site.

The long-term heavy grazing pressure changes plant community species composition and structural diversity (Bai et al. 2001), range health and productivity (Goebel and Cook 1960, Willms et al. 1986) which results in greater annual yield fluctuations (Heitschmidt et al. 1989). Furthermore, Heitschmidt et al. (1989) determined that the species would shift towards a community composed of less palatable, less productive, and more grazing tolerant species (i.e. short-grasses). Conversely, moderately grazed lands can actually be healthier than ungrazed range, maintaining species and structural diversity (Collins et al. 1998, Smith et al. 1996, Johnston 1961), producing more forage (Stelljes and Senft 1994, Howitt 1995), and potentially supporting more wildlife (Smith et al. 1996). Diverse plant communities, often attributed to micro-site diversity created by grazing (Bai et al. 2001), may be more resistant to disturbances (McNaughton 1985, Tilman and Downing 1994). Bai et al. (2001) recommend that species diversity should be an important management consideration in view of potential benefits to livestock producers and wildlife.

2.1.3 Invaded Fescue Prairie

Sampson (1919)(as quoted by Dyksterhuis 1949) concluded, "The most rational and reliable way to detect overgrazing is to recognize the replacement of one type of plant cover by another". More recently, the Society for Range Management (1974) defined invasive plants (i.e. invaders) as, "Plant species that were absent in undisturbed portions of the original vegetation of a specific range site and will invade or increase following disturbance or continued heavy grazing".

In a synthesis paper, Masters and Sheley (2001) indicated invasive plants alter ecological processes and systems thereby reducing their ability to provide the benefits they afford man and nature (e.g. livestock forage and habitat) (also Willms et al. 1996). The presence of invasive species was often indicative of underlying management problems that must be recognized and corrected to attain long-term sustainability of rangelands (Masters and Sheley 2001). However, views of desirable plants may differ among resource managers (Moss and Campbell 1947).

Sites that have fewer plant species, nutrients and less moisture (e.g. steppes) are less susceptible to invasion than those that are highly diverse, which also tend to have adequate nutrients and moisture (Masters and Sheley 2001). Willms (1988b) noted that fescue prairie sites with superior moisture are often invaded by species like Kentucky bluegrass (*Poa pratensis* L.) under heavy grazing pressure.

Beaty and Engel (1980) suggested that native species tend to produce only one set of tillers per season, which was thought to be a drought survival tactic. Introduced cultivars [e.g. Kentucky bluegrass and smooth brome (*Bromus inermis* L.)] produce more than one crop of tillers per season which may make them more susceptible to drought (Beaty and Engel 1980) and more vulnerable in sites with fluctuating moisture.

Coupland and Brayshaw (1953) found little evidence of Kentucky bluegrass or smooth brome in Saskatchewan fescue grasslands. Conversely in Alberta, Moss and Campbell (1947) revealed that the Fescue Association, with rough fescue growing almost to the exclusion of other species, existed in pristine form only as rare relict areas. Interestingly, losses due to invasion by agronomic species and weeds were not noted, but Moss (1944) recorded the presence of six invaders (generalized as weeds and grasses). Smooth brome or Kentucky bluegrass were not recorded as part of the fescue association, implying that they were invading species occupying denuded areas or sites altered by grazing (Moss 1944, Moss and Campbell 1947).

Rough fescue was reduced then eliminated under heavy or indiscriminate grazing (Moss and Campbell 1947). Several studies indicate that rough fescue was replaced (McLean and Tisdale 1972, Willms et al. 1985, 1990, 1996) by species that were less productive, shallow rooted but more resistant to grazing (Dormaar and Willms 1990, 1998, Dormaar et al. 1989, Willms et al. 1988, 1996). For example *Bouteloua gracilis* (H.B.K.) Lag. was found to dominate eastern slopes of the Porcupine Hills, which were previously dominated by rough fescue (Moss 1944, Moss and Campbell 1947). They also commented that species replacing plants of the fescue association have become so common as to give the impression that they always belonged there.

Continuous grazing, at various stocking rates, led to patch establishment and maintenance (Willms et al. 1988) even in a near monoculture pasture (Cid and Brizuela 1998). Within rough fescue grasslands, overgrazed patches were dominated by seral species such as bluegrasses while undergrazed areas were dominated by rough fescue and Parry oat grass (*Danthonia parryii* Scribn.) (Willms et al. 1988). They concluded that patches were stable over the long-term, as indicated both by plant species composition and soil differences (also Dormaar et al. 1989, Dormaar and Willms 1990, 1998). Patches varied in the degree of utilization (Cid and Brizuela 1998) and litter accumulation (Willms et al. 1988, 1996). Those that were heavily used had less biomass, higher nitrogen concentration, and were revisited by cattle even though they covered less than 30% of the area (Cid and Brizuela 1998). Cattle grazing at low to moderate stocking rates, could benefit nutritionally from patch grazing (Cid and Brizuela 1998) and preferred the regrowth in these areas to more mature forage found in undergrazed patches (Willms et al. 1988).

As long-term grazing intensity increased, the rough fescue dominated grasslands deteriorated to a Parry oat grass - Kentucky bluegrass community, then to a Kentucky bluegrass - upland sedge community (Willms et al. 1996). Deteriorated range had reduced productivity (Willms et al. 1985) providing less of its peak production in the spring, and undergoing greater dry matter losses over winter compared to rough fescue dominated grasslands (Willms et al. 1996). Similarly, other researchers found that Kentucky bluegrass replaced native fescue species as grazing pressure increased (Bai et al. 2001, Schwan et al. 1949). Recovery of invaded fescue grasslands was estimated to be longer than ten years and may be longer than 40 years (McLean and Tisdale 1972, Dormaar and Willms 1990) depending on initial range condition, rainfall and management during the recovery period (Sims and Gillen 1999).

Masters and Sheley (2001) indicated that disturbance was critically important to weed invasion by opening niches and allowing resources to become available. Management decisions regarding invasive species should not be made in isolation of other management goals (McLean and Tisdale 1972, Masters and

Sheley 2001).

2.1.4 Productivity

Agriculture and Agri-Food Canada (1992) provides sample production and stocking rates on fescue grasslands (Table 2.1). Willms and Rode (1998) suggested a sustainable winter (i.e. dormant season) stocking rate was 3.2 AUM/ha. A moderate (growing season) stocking rate of 1.6 AUM/ha is considered conducive to maintaining fescue grassland in good range condition (Willms et al. 1985, Wroe et al. 1988), a healthy state (Dormaar and Willms 1990) and limited removal of the current year's phytomass to 50 to 36% (Dormaar and Willms 1990, Willms et al. 1985, respectively).

It is commonly agreed that maximum production can be achieved by delaying grazing until plants are in a stage of rapid growth and by limiting the amount of photosynthetic material removed. Furthermore, forage production (and species phenology), was affected by topographic characteristics which were related to climate and soil variation (Willms 1988b). Willms et al. (1985) indicated that historical and continued heavy grazing, rather than climate or soil variation, kept some areas in a regressed seral state, which consequently caused varying responses in grass and forb production (Bai et al. 2001). Moderate grazing pressure likely had a greater negative impact in these situations compared to good condition rangeland. Stocking at the recommended rate when the range was in less than good condition allowed a very modest rate of recovery compared to the rate of recovery demonstrated by a 38% reduction of grazing pressure (Willms et al. 1985). Therefore, stocking rates should be adjusted for both range condition and site potential.

2.1.5 Grass Growth and Response to Defoliation

Although there have been extensive studies on forage growth and the effects of grazing or other means of defoliation on forage species, few have specifically considered the species of interest in the current study. Therefore, a general review of plant growth and plant response to defoliation follows, with species specific information reviewed in subsequent sections.

Grasses have evolved as the dominant forage plant because they can produce tillers and/or maintain a low growing point allowing leaf formation to continue during and after defoliation (Langer 1972). The production of phytomers represents growth in grasses (Evans and Grover 1940). Phytomers are composed of several parts including a leaf blade, leaf sheath, node, internode, axillary bud, and sometimes an adventitious root (Beaty and Engel 1980). Several phytomers make up the shoot or tiller. Forage yield is determined by the size and number of tillers (Beaty and Engel 1980, Willms et al. 1980). Tiller initiation is probably related to energy and mineral concentration in the basal axillary buds in mid to late summer (Langer 1972). Tiller competition occurs under environmental stress and the life span of a grass plant is only limited by its ability to perpetuate viable tillers. The number of live leaves on a tiller is relatively stable and related to environmental conditions (Langer 1972) but emergence and growth rates were species specific (Beaty and Engel 1980).

In a greenhouse study, Branson (1956) reported that the growth of roots and shoots was inversely proportional to the intensity of clipping. Similarly, in response to grazing, roots were slower to recover than shoots, and had declining volume and growth as grazing frequency and severity increased (Alcock 1964, Hild et al. 2001). Deep roots decomposed after grazing and absorption potential was reduced and narrowed to upper limits of the soil (Alcock 1964, Skinner et al. 2002). Conversely, Hild et al. (2001) found only shallow roots were affected by grazing.

The carbohydrate reserves of ungrazed plants are usually the lowest after initial spring growth and peak near plant maturity (Trlica and Cook 1971). They also indicated that the depletion of reserves through herbivory was believed to be a primary factor for the loss of plant vigor and subsequent reduction in range health.

Willms et al. (1980) found that the ratio of weight to volume (i.e. total density) was not different among the undefoliated and defoliated treatments, but fall clipping caused a redistribution of weight to a lower position on the plant. Pitt (1986) reported that clipping up to the phenological stage of seed formation, resulted in improved fall forage digestibility (ADF) and quality (crude protein). The effect of clipping treatments on crude protein and fibre distribution within a plant was variable among study sites (Willms et al. 1981).

In a review of plant-animal interactions, Coughenour (1991) suggested that studies of plant recovery from grazing should not be limited to periods of less than a full year. In addition, the sward may compensate for random plant defoliation through the decrease in intra-plant competition that would allow ungrazed neighbours to flourish. He went on to say that the landscape scale of plant responses to herbivory could not be assumed to be equal to the plant scale. For example, results of grazing the sward at a uniform 50% utilization could be very different from the result of grazing 50% of the plants at 100% utilization. Indeed, it was unlikely that any plant would be grazed in an "average" way if there were varying plant communities or favoured patches present. Coughenour (1991) concluded that in order to relate plant scale response to the landscape level, one must incorporate spatial information regarding plant communities or patches.

2.2 Smooth Brome

Smooth brome is a rhizomatous, long-lived perennial introduced to North America circa 1888 from Europe (Walton 1983) and Siberia (Looman 1983). It is a drought tolerant temperate cool-season grass (Walton 1983). Smooth brome has a dense, shallow root system with some roots extending to 1.5 meters (Looman 1983). Tillers are frequently reproductive with relatively broad, soft dropping leaves. Smooth brome is recognized as a palatable grass from the time of growth initiation in early May to the heading stage, after which only the leaves and seeds are selected (Looman 1983). Protein content and digestibility was shown by Looman (1983) to be about 22 and 60% in May declining to about 6 and 40%, respectively, by September.

Smooth brome is known as an aggressive species commonly used for pasture, hay, and roadside reclamation and often escaping into native areas forming large patches. Walton (1983) recommended that it be grazed in a rotation, with defoliation approximately four times per season.

2.3 Kentucky Bluegrass

Kentucky bluegrass is also commonly referred to as Junegrass and smooth-stalked meadow grass (Walton 1983). Although first introduced from Eurasia in about 1625, there was more than one introduction (Walton 1983). It spreads rapidly, having the ability to form seeds without fertilization (apomixes) (Walton 1983), and was nicknamed "white man's foot grass" by the North American Indians. Looman (1983) suggested that it was so widely distributed in North America and had invaded native rangelands to such an extent that it was often considered to be native (McLean and Tisdale 1972).

Kentucky bluegrass is a perennial sod-forming cool-season grass and prefers areas with a cool, moist (over 500 mm) climate and relatively fertile soil (Walton 1983, Looman 1983). Overgrazed patches often had these properties (Coughenour 1991) and therefore would be favourable for Kentucky bluegrass establishment and perpetuation. Although an aggressive, grazing resistant (Branson 1956, Ellison 1960) species in favourable conditions, it can not survive when competing with taller species (Ellison 1960) or under persistent heavy grazing (McLean and Tisdale 1972) causing soil moisture limitations (Bai et al. 2001). About 80% of Kentucky bluegrass roots were found in the upper 15 cm of soil, severely limiting its yield potential and vigor in times of moisture stress (Walton 1983).

Kentucky bluegrass has relatively narrow, soft, lax leaves, which make it better suited to grazing than haying. It was found to be a highly productive, long-lived species, that flourished under repeated close defoliation (Walton 1983, Looman 1983). Walton (1983) recommended that bluegrass be utilized in the spring when it was most productive, palatable and nutritious. Looman (1983) noted that protein levels are about 30% in spring and drop rapidly if the plant is not maintained in a vegetative state.

2.4 Parry Oat Grass

2.4.1 Taxonomy and Habitat

Parry oat grass is a native cool-season perennial bunchgrass with persistent sheaths. Moss and Campbell (1947) determined that it ranged from southwestern Alberta to New Mexico. In Alberta, it was thought to be largely restricted to the western part of the fescue prairie region (Moss 1944), where it dominated wind blown slopes (Moss and Campbell 1947) and dry sites with shallow or gravelly soil profiles (Wroe et al. 1988). It was often found as a co-dominant with rough fescue in the fescue prairie (Moss 1944).

2.4.2 Response to Grazing and Defoliation

Parry oat grass replaced rough fescue on historically heavily grazed grasslands (Moss and Campbell 1947, Willms et al. 1985). Willms et al. (1985) noted that Parry oat grass increased under light (1.2 AUM/ha) to moderate or heavy (2.4 AUM/ha) stocking, but declined with very heavy (4.8 AUM/ha) grazing pressure.

Willms (1991) found that Parry oat grass was less productive than rough fescue. He indicated that the response of these two species to a variety of clipping frequencies and clipping heights was similar in the first year of treatment. However, after three years (and presumably as early as two years), Parry oat grass prevailed as being more resistant to both clipping height and frequency compared to rough fescue. Moreover, Parry oat grass yields were enhanced when severely clipped (5 cm) at low frequency (1 to 2 times per year). Parry oat grass experienced minimal plant mortality and increased ability to regrow after clipping compared to rough fescue (Willms 1991).

Willms and Rode (1998) found that rough fescue was preferred over Parry oat grass in both winter and summer. Utilization of both species was greater in the summer versus winter, and greater for rough fescue in both seasons.

2.5 Rough Fescue

2.5.1 Taxonomy and Habitat

What started as a single rough fescue species (*Festuca altaica* Trin. or *F. scabrella* Torr.) has since been recognized as a complex of three unique species, northern, mountain (foothills), and plains rough fescue [i.e. *F. altaica* Trin., *F. campestris* Rydb., and *F. hallii* (Vasey) Piper respectively]

(Aiken and Lefkovitch 1984). Pavlick and Looman (1984) discussed both the taxonomy and nomenclature of the rough fescue taxa found in Canada and parts of the United States. They also provide detailed descriptions and a key to the three species.

King et al. (1995) summarized the locale and climatic criteria of the three species. *F. hallii* and *F. campestris* were predominantly found at elevations below subalpine regions. *F. campestris* occurs at 1000-1700 meters above sea level (masl) and *F. hallii* below 1000 masl (Breitung 1957). *F. hallii* and *F. altaica* favour warmer temperatures and moist summers whereas *F. campestris* prefers areas of cooler temperatures and moist springs and dry summers (King et al. 1995). Considering growing season precipitation and temperatures, *F. hallii* and *F. campestris* occupy areas with similar precipitation to evaporation ratios. The tufted growth form suggests that *F. campestris* was adapted to dryer climates, while plants having rhizomes, like *F. hallii,* appear to be adapted to more mesic areas (King et al. 1995, Johnston and Cosby 1966). *F. hallii* and *F. campestris* both had smaller tillers and greater tillering rates than *F. altaica,* which King et al. (1995) suggested was an adaptation to bison herbivory, enabling survival. Both species curtailed growth at temperatures above 20°C which may be an evolutionary response to drought conditions, and could have a flush of late season (September) growth if moisture was available.

2.5.2 Growth

Johnston and MacDonald (1967) and Stout et al. (1981) described in detail the phenological development of rough fescue (*F. campestris*). Generally, visible growth was underway by mid April to early May when soil was about 2 to 3.8°C. Bogen (2001) reported that the majority of rough fescue growth was achieved by early to mid May, but maximum production occurred by early to the end of July (Willms and Fraser 1992, Stout et al. 1981). Vegetative growing points remained close (2.3 mm) to ground level throughout the year, but the growing points of initiated reproductive culms were gradually elevated from 3.5 to 15.2 mm over the growing season (Johnston and MacDonald 1967). Sinton (1980) found that more tillers were initiated in the fall and speculated that it commenced with the onset of cooler weather.

It appears that growth is terminated at about 10% soil moisture (Stout et al. 1981). In greenhouse experiments, plant height and growth was reduced when soil water content was below 60% field capacity, an uncommon field condition (Willms 1988a). Plants continued to gain weight after leaf growth stopped (Stout et al. 1981, Stoddart et al. 1975). Stout et al. (1981) articulated that this was expected because growth (i.e. cell expansion) and not photosynthesis was more sensitive to moisture stress. They also concluded that year-to-year variability of growth was similar to site-to-site variability at the time of their study.

2.5.3 Response to Grazing and Defoliation

Many studies considered the effects of season, frequency, severity and duration of defoliation on rough fescue (*F. campestris* and *F. hallii*). Generally, the response was similar among taxa but dependent on the level of each of those main effects, and at times their interactions were significant. Several of the studies are briefly discussed below because of their relevance to the current study.

McLean and Wikeem (1985) and Sinton (1980) found that clipping in early spring (prior to 15 May) was less stressful to plants than the late spring treatment (mid May to late June). Plants clipped in late spring had greatly reduced regrowth and carbohydrate reserves in the fall compared to those clipped later (McLean and Wikeem 1985). The effects of clipping both in early spring and again in fall was similar to the early spring treatment, and was less damaging than the late spring and fall clipping combination. McLean and Wikeem (1985) speculated that early spring treatments allowed the plant to recover better and be less dependant on fall production of assimilates. Fall regrowth of rough fescue was suppressed by weekly clipping (Stout et al. 1981) or any defoliation during the growing period (Sinton-Gerling et al. 1994).

Sinton (1980) noted that rough fescue growth on defoliated plants appeared up to three weeks earlier but was reduced (also Willms and Fraser 1992, McLean and Wikeem 1985). *F. hallii* response to defoliation was to produce a greater number of shorter phytomers, which was thought to be indirectly induced by removal of living and dead plant material, which increased solar energy reaching the plant (Sinton 1980). A similar response of clipped *F. campestris* (to remove standing litter) was also noted by Willms (1988a).

Willms (1991) reported that rough fescue (*F. campestris*) yields were adversely affected after one year of clipping more than 4 times per year or at a height of 5 cm. After three, and presumably as early as two (Willms 1991), or four (Willms and Fraser 1992) years of sustained treatments, rough fescue yields were significantly affected by clipping frequency alone. All of the frequencies examined greatly reduced yields, except clipping once on 28 August. The greatest plant mortality was observed at the most extreme clipping heights and frequencies.

Willms and Fraser (1992) found that removal of biomass once per season (28 August) for three years had no effect on tiller weight or numbers per plant compared to a control (similar to Bogen 2001, but contrary to Willms 1988a greenhouse study, and Sinton 1980 field study of *F. hallii*). The yield per plant was similar to the control when biomass removal was limited to a height of 15 cm administered once per season for three years followed by a full seasons rest. Although no analysis was done to test the differences among one time administered clipping heights (i.e. 5, 10, or 15 cm), the trend was for more severe clipping to have a greater negative impact on plants. It was also determined that the response of rough fescue plants to individually applied treatments appeared to stabilized as early as year two (Willms 1991) and continued up to at least year four (Willms and Fraser 1992).

Bogen (2001) studying previously protected plants determined that May versus September defoliated plants had significantly lighter tillers in the first spring after treatment. However, after one year of complete rest, plant phytomass was only slightly reduced, indicating that plants had recovered after one season of rest, this corroborated earlier studies (Willms and Fraser 1992, Willms 1991 and McLean and Wikeem 1985).

Historically, rough fescue was the winter grass of buffalo herds on the Northern Great Plains and evolved under that grazing regime (Johnston and MacDonald 1967). Winter grazing did not kill or reduce the vigor of rough fescue (Johnston and MacDonald 1967, McLean and Wikeem 1985). However, it was sensitive to spring (Willms 1991, McLean and Wikeem 1985, Clark et al. 1998) and sustained heavy summer use (Johnston and MacDonald 1967).

2.6 Litter

Many researchers define litter to include both standing dead and downed herbaceous necromass (Reese et al. 1980, Willms 1988a). In other definitions, litter is described as "the uppermost layer of organic matter on the soil surface; essentially the freshly fallen or slightly decomposed vegetal material" (Society for Range Management 1974). Litter is commonly referred to as any dead plant material that has only slightly decomposed and unless otherwise noted, is the definition used here.

Average litter accumulations in rested or ungrazed fescue prairie range from 2820 kg/ha (Willms et al. 1986) to 5842 kg/ha (Sinton 1980) for parkland grasslands (*F. hallii*) and 4000 kg/ha to 9030 kg/ha for foothills grasslands (*F. campestris*) (Moisey and Adams 2002). Extreme levels up to 12,400 and 15,400 kg/ha were noted by Johnston (1961), and Moisey and Adams (2002) respectively. Johnston (1961) determined that marginally cooler and moister spring soil conditions were attributed to the heavier accumulation of mulch on ungrazed sites.

Litter cover decreased the soil temperature and delayed spring growth of warm-season grasses (Rice and Parenti 1978), while favouring root growth of cool season grasses, which was lower than the optimal temperature for shoot growth (Langer 1972). Under low light intensity (as would occur in dense growth conditions), root growth and survival was affected much more than shoot growth (Langer 1972). Shaded shoots had reduced carbohydrate production which caused a decline in root growth. Conversely, Sauer (1978) found that removing standing litter produced shorter leaves and reduced plant weights in bluebunch wheatgrass (a cool-season grass). He concluded that shading by standing litter was beneficial to bunchgrasses growing in arid (200 mm precipitation) climates. Similarly, Moss and Campbell (1947) speculated that *F. campestris* increased in vigor if protected and shaded by standing litter.

Within fescue grassland, increasing grazing intensities generally reduced the height, cover, accumulation, and thickness of standing litter (Naeth et al. 1991, Bai et al. 2001). Grass yield was not significantly affected by up to three years of repeated spring (dormant season) removal of litter (Willms et al. 1986). They also determined that tiller height, weight, or density response to removal of mulch and standing litter (at either 5 or 15 cm) during dormancy was not affected by the season of removal (i.e. spring versus fall). In the first year, tillers on plants subjected to litter removal were significantly shorter compared to the control, and by the second year all three treatments were significantly different. Litter removal did not affect total plant weight, but appeared to increase tiller numbers. *F. hallii* and *F. campestris* responded similarly to litter removal (Willms et al. 1986).

An abnormal decline of litter caused by heavy grazing (Gillen et al. 2000, Willms et al. 1988), would likely lead to a change in nutrient cycling (Coughenour 1991, Cid and Brizuela 1998). The addition of organic matter through litter degradation also increased soil moisture infiltration rates (Goebel and Cook 1960). Litter was also an important factor affecting range recovery, and contributed to the stability of forage production (Schwan et al. 1949) in drought years, but having no effect when rainfall was near normal (Willms 1988b).

Pfeiffer and Hartnett (1995) found that persistent standing litter of little bluestem was a deterrent to grazing by bison. Indeed, many researchers have considered the effects of litter as an anti-quality reducing herbivory (Flores et al. 1993, Ganskopp et al. 1992, Willms and Rode 1998). Most structural anti-quality characteristics of plants affected the rate of utilization (Laca et al. 2001). Plants without stems (Ganskopp et al. 1992), or without high litter accumulation (Willms and Rode 1998) were more likely to be grazed and had greater levels of utilization. Similarly, Flores et al. (1993) determined that the negative effect of stem presence was evident only if they were higher than the biting depth animals would normally select in a sward lacking stems. Laca et al. (2001) recognized the benefit of structural anti-quality (e.g. standing litter) in promoting the stability of grazing systems by preventing severe defoliation or by providing plant refuges for highly desirable forages.

2.7 Grazing Behaviour as Related to Forage Preferences

Preference (i.e. resource selection as related to animal behaviour) was summarized by Heady (1964) as being determined by four broad factors that were interrelated. The first factor was a combination of interrelated site conditions (soil factors, moisture regime, etc.) and plant community composition (sward structure, species relative abundance and production, etc.). The second factor was palatability, which was based on the characteristics of a plant or food that animals can detect and respond to. His review of the subject revealed that no single characteristic explained preference but that chemical composition of the food was relatively important. The recent and evolutionary experience of the animal was the third factor. Last, the physiological state of the animal was noted as having an impact on preference.

2.7.1 Availability of Forage

In a review of earlier work, Heady (1964) suggested that a complex interaction of many factors led to a stimulus-response chain reaction of events that included location of food, appraisal, ingestion, and cessation of eating by livestock. This conclusion was supported by more recent work (Allen and Segarra 2001, Burritt et al. 2000, Laca 1998, Hein and Miller 1992, Owens et al. 1991, Willms et al. 1988, Allison 1985, Thornton and Minson 1973, and others).

The array of choice open to the grazer was first determined by availability of forage species, which then indirectly affected preference. Lazo and Soriguer (1993) reported that intake behaviour was influenced by extrinsic factors such as abundance and plant communities. Abundance generally equalled availability, however, there were some cases where a plant was abundant but not available due to protection of some kind. Snow cover, for instance, may protect some species from winter grazing while forcing use of others thereby influencing forage preferences (Willms and Rode 1998, Pfister et al. 1998) while attempting to maximize intake (Westoby 1974). Conversely, others have concluded that a species was utilized based on cattle preference for it, and not influenced by plant abundance or biomass (Hurd and Pond 1958, Allison 1985, Gillen et al. 1984, and Ayantunde et al. 1999). Willms et al. (1980) stated that biomass availability and indirectly, bite size, was determined by plant species physiological characteristics (e.g. growth rate, height, etc.) and may explain some of these conflicting results.

Forage utilization was effected by stocking rate (Willms at al. 1985) and availability (Popp et al. 1997, Scarnecchia et al. 1985). Willms at al. (1985) estimated that forage utilization increased from 26, to 36, to 47, and to 81% for light, moderate, heavy and very heavy stocking rates, respectively. Declining forage availability caused cattle to graze longer (Popp et al. 1997, Scarnecchia et al. 1985) or to discontinue feeding after their requirements for maintenance and some for growth were met (Hepworth et al. 1991). Eating more for additional growth was not energy efficient due to the limited forage resource (Hepworth et al. 1991). Wallis de Vries and Schippers (1994) also discussed the notion that the costs of grazing selectively might be greater than its benefits. Under minimal supervision, cattle may exercise their own rotation based on 51-75% utilization before moving to another area to forage (Squires 1982). Short, high quality plants with less biomass per area, were preferred over tall, low quality plants to maximize nutrient intake (Wallis de Vries et al. 1999, Cid and Brizuela 1998).

O'Reagain and Grau (1995) explained that a basic prediction of the optimal foraging theory was that dietary breadth would widen as food availability declined (Emlen 1966) with foods being added to the diet in the order of their utility to the animal (Pyke et al. 1977). O'Reagain and Grau (1995) determined that animals grazed (and regrazed) preferred and intermediately preferred species until 80 to 100% of the tillers were used, then grazed the avoided species. Similarly, livestock consistently took more bites from preferred forages and re-grazed preferred plants before any species was depleted (Ganskopp et al. 1997, Cruz and Ganskopp 1998, Willms and Rode 1998, Springfield and Reynolds 1951). O'Reagain and Grau (1995) determined that, assuming that the theory was correct and preference was a function of utility, the observed sequence of selection gave evidence supporting the prediction. They concluded that the basic concept of non-selective grazing under high stocking pressure was incorrect and largely unattainable.

Smith et al. (1992a, 1992b) found that the disproportionate cattle use of riparian areas was related to the higher amounts of forage available in those areas. Many other researchers have made similars conclusions (Roath and Krueger 1982, Gillen et al. 1984, Kie and Boroski 1996, Moorefield and Hopkins 1951).

2.7.2 Factors Affecting Intake

Beaty and Engel (1980) suggested that a 500 kg beef cow would eat 3% of her body weight in forage DM/day, a steer 1.5 - 2.5%. Forage intake and quality was more important to young cattle, which generally had higher energy requirements. The actual level of food intake by ruminants has been related to body size, physiological status, nutrient supplementation, forage preferences, and forage availability, which had varying impact (Allison 1985).

Voluntary forage intake by ruminants was regulated by rumen fill, rate of digesta passage and forage digestibility (Allison 1985, Okine et al. 1996). Cows would eat more if hay was removed from the rumen, but the addition of water to the rumen did not affect intake (Campling and Balch 1961). Although water did not affect intake, relatively succulent plants were more likely to be selected (Allison 1985) or plants with higher rates of rumen degradation (Okine et al. 1996, Van Wieren 1996). When plant cells thicken and lignify (i.e. mature) they become more resistant to decomposition and resist the changes in specific gravity required to pass through the rumen (Beaty and Engel 1980, Adams et al. 1987, Thornton and Minson 1973).

2.7.3 Nutritional Wisdom

Provenza (1995) suggested that ruminants select foods that meet their specific nutritional needs and avoid ones that could cause toxicosis. In his view, nutritional wisdom does not occur from the animal directly tasting the nutrients or toxins but rather by postingestive feedback. Other research suggests that taste and smell, in addition to postingestive feed back, contribute to nutritional wisdom (Provenza et al. 1992, Burritt et al. 2000, Pfister et al. 2001). Provenza (1999) indicated the feedback interaction was stronger than the influence of learned behaviour from the animal's mother. He defined palatability as the inter-relationship between flavour and postingestive feedback, determined by an animal's physiological condition and food chemical characteristics. Malaise (discomfort) was caused by excesses of either nutrients or toxins and by hunger or nutrient deficits in relation to the animal's specific requirements. Satiety (the feeling of fullness), or malaise caused the animal to acquire either mild or strong preferences or aversions to foods. A change in the animal's behaviour was in response to a gradual worsening deficit of a nutrient or excess of either a nutrient or toxin. The animal would start sampling other foods or plants in an attempt to restore balance in its diet. Generally, animals would stick to the foods that they were familiar with. Provenza (1999) indicated the intake of a newly introduced food would sharply fall when fed with familiar foods treated with a toxin. The animals initially tried to avoid the discomfort of the toxin by not eating the new food. The sooner the negative feedback followed the ingestion and flavour of a food, the less likely the animal was to continue the selection of a plant.

Nutritional wisdom, expressed as preference, was influenced by past use and perpetuated the cycle of habitat selection (Musimba et al. 1987, Willms et al. 1988). Similarly, Wallis de Vries et al. (1999) found that selection of recognizable patches was predictable based on nutrient intake maximization. Selected diets, presumably composed of preferred species, were of greater quality than the average available to livestock (Ayantunde et al. 1999, Popp et al. 1999, Jung and Koong 1985, Ganskopp et al. 1997, Cid and Brizuela 1998, Cruz and Ganskopp 1998). Selecting a variety of plants was nutritionally beneficial (Herbel and Nelson 1966) but in some cases, animals developed an "addiction" to harmful plants (Ralphs et al. 1993).

2.7.4 Avoidance

Anti-quality factors of prospective foods may have an important affect on animal behaviour and adaptation (e.g. nutritional wisdom), (Launchbaugh et al. 2001, Allen and Segarra 2001, Pfister et al. 2001, Provenza et al. 1992). These anti-qualities have the potential to reduce intake digestibility, cause nutritional imbalances, do mechanical damage, or affect internal systems. Examples of anti-qualities are tannins, coumarins, nitrates (Heady 1964), alkaloids (Pfister et al. 2001), manure cover (Plice 1952), and certain physical plant attributes (Willms et al. 1988, Ganskopp et al. 1992, Willms and Rode 1998, Laca et al. 2001). Physical anti-quality factors could substantially influence search and cropping time, bite size, digestion, and quality of animal products (Laca et al. 2001). They suggested that the degree of influence was dependent on the morphology of the animal and the plant, as well as the plants abundance and density on the range.

Launchbaugh et al. (2001) discussed the adaptive mechanisms that herbivores possess to decrease the impacts of anti-quality factors. It was succinctly put and thus quoted below.

> *"First, herbivores graze selectively to limit consumption of potentially harmful plant compounds. Grazing animals rely on a sophisticated system to detect plant nutritional value or toxicity by relating the flavour of a plant to its positive or negative digestive consequences.*

> *Diet selection skills were enhanced by adaptive intake patterns that limit the deleterious effects of plant allelochemicals; these include cautious sampling of new foods, consuming a varied diet, and eating plants in a cycle, intermittent, or carefully regulated fashion. Second, grazing animals posses internal systems that detoxify or tolerate ingested phytotoxins. Animals may eject toxic plant material quickly after ingestion, secret substances in the mouth or gut to render allelochemicals inert, rely on rumen microbes to detoxify allelochemicals, absorb phytochemicals from the gut and detoxified them in body tissues, or develop a tolerance to the toxic effects of plant allelochemicals."*

There have been many studies of the anti-quality factors of common range plants (Pritz et al. 1997, Landau et al. 1999, Burritt et al. 2000, Banner et al. 2000, Bisson et al. 2001, and others). Researchers have tried to find ways to increase intake or decrease the harmful effects, or simply to learn more about the animal behaviour associated with plant species avoidance.

2.7.5 Forage Quality

As plants matured and senesced, forage quality (Beaty and Engel 1980) and preference were reduced. Many have studied and correlated plant maturity with plant utilization (Heady 1964, Reppert 1960, Ganskopp et al. 1997, Dwyer et al. 1964). However, after senescence, some species were preferred (e.g.

smooth brome) by cattle, while others were avoided (e.g. Kentucky bluegrass) (Springfield and Reynolds 1951). Adams et al. (1987) found that intake was not affected by forage maturity. Bezeau and Johnston (1962) and Johnston and Bezeau (1962) reported some nutritive qualities of various species within the fescue grasslands (see Table 2.2).

When forbs were green, and still available (i.e. not mature and disintegrated), they were highly preferred over grass species (Holechek et al. 1982, 1987, Strasia et al. 1970). Holechek et al. (1982, 1987) reported that the botanical composition of cattle diets was most diverse during the early grazing periods when all species were in early stages of development. Cattle diets were predominantly composed of grass species during later grazing periods (Holechek et al. 1982, 1987), while sheep were more selective in their choice of grass and sedge species but ate most forbs readily (Strasia et al. 1970). Other researchers have found that livestock preferences for plant species were altered with season (Mohammad et al. 1996, Askins and Turner 1972, Pearson et al. 1971, Clary and Pearson 1969), or plant community (Kie and Boroski 1996). Hurd and Pond (1958) found no preference of forbs over grasses.

Generally, those species (Ganskopp et al. 1997, Van Wieren 1996) or plant parts (Heady 1964, Reppert 1960, Olson and Wallander (2001) of higher nutrient quality were preferred (Allinson 1969, Beaty and Engel 1980) although not always (Olson and Wallander 2001). Additionally, species were not always ranked at the same level of preference when comparing different community types (Tomanek et al. 1958, Clary and Pearson 1969, Olson and Wallander 2001).

Heady (1964) determined that in most studies he reviewed correlated preference of plant species or community (Senft et al. 1985), to a group of plant chemical characteristics. However, early research suggested that protein offered the best partial correlation to preference (Heady 1964). Wallis de Vries and Schippers (1994) found that total nutrients, and particularly phosphorus, rather than just energy proved to be relatively significant in determining habitat and plant selection.

2.8 Literature Cited

Adams, B.W., M.L. Anderson, and L. Cole. 1993. Alberta rangeland resources. Presented to the first Inter-provincial Range Conference in Western Canada, Saskatoon, Saskatchewan. January 17-20, 1993.

Adams, D.C., R.C. Cochran and P.O. Currie. 1987. Forage maturity effects on rumen fermentation, fluid flow, and intake in grazing steers. J. Range Manage. 40:404-409.

Agriculture and Agri-Food Canada. 1992. Handbook 1: Foothills fescue prairie. Publication #1883/E.

Aiken, S.G., and L.P. Lefkovitch, 1984. The taxonomic value of using epidermal characteristics in the Canadian rough fescue complex (*Festuca altaica, F.campestris, F.hallii, F.scabrella*)Can. J. Bot. 62:1864-1870.

Alcock, M.B. 1964. The physiological significance of defoliation on the subsequent regrowth of grass-clover mixtures and cereals. P 25-41. *IN*. Grazing in terrestrial and marine environments. Ed. DJ Crisp. Blackwell Scientific Publication. Oxford.

Allen, V.G., and E. Segarra. 2001. Anti-quality components in forage: Overview, significance and economic impact 1. J. Range Manage. 54:409-412.

Allinson, D.W. 1969. Forage lignin's and their relationship to nutritive value Proc. National Conf. On forage quality, evaluation and utilization. p.51-59.

Allison, C.D. 1985. Factors affecting forage intake by range ruminants: A review. J. Range Manage. 38:305-311.

Askins, G.D., and E.E. Turner. 1972. A behavioral study of Angora goats on west Texas range. J. Range Manage. 25:82-87.

Ayantunde, A.A., P. Hiernaux, S. Fernandex-Rivera, H. Van Keulen, and H.M. Udo. 1999. Selective grazing by cattle on spatially and seasonally heterogeneous rangeland in Sahel. J. Arid Environ. 42:261-279.

Bai, Y., Z. Abouguendia, and R.E. Redmann. 2001. Relationship between plant species diversity and grassland condition. J. Range Manage. 54:177-178.

Banner, R.E., J. Rogosic, E.A. Burritt, and F.D. Provenza. 2000. Supplemental barley and charcoal increase intake of sagebrush by lambs. J. Range Manage. 53:415-420.

Beaty, E.R. and J.L. Engel. 1980. Forage quality measurements and forage research. A review, critique and interpretation. J. Range Manage. 33:49-54.

Bezeau, L.M. and A. Johnston. 1962. In-vitro digestibility of range forage plants of the *Festuca scabrella* association. Can J. Plant Sci. 42:692-696.

Bisson, M.G., C.B. Scott, and C.A. Taylor. 2001. Activated charcoal and experience affect intake of juniper. J. Range Manage. 54:274-278.

Bogen, A.D. 2001. Foothills rough fescue response to fire and defoliation. M.SC. Thesis Univ. of Alberta. Edmonton, AB.

Branson, F.A. 1956. Quantitative effects of clipping treatments on five range grasses. J. Range Manage. 9:86-88.

Breitung, A.J. 1957. Plants of Waterton Lakes National Park, Alberta. Canada. Field-Nat. 71:39-71.

Burritt, E.A., R.E. Banner, and F.D. Provenza. 2000. Sagebrush ingestion by lambs: Effect of experience and macronurients. J. Range Manage. 53:91-96.

Campling, R.C., and C.C. Balch. 1961. Factors affecting the voluntary intake of food by cows. I. Preliminary observations of the effect, on the voluntary intake of hay, of the changes in the amount of the recticulo-ruminal contents. Brit. J. Nutr. 16:523-530.

Cid, M.S., and M.A. Brizuela. 1998. Heterogenity in tall fescue pastures created and sustained by cattle grazing. J. Range Manage. 51:644-649.

Clark, P.E., W.C. Krueger, L.D. Bryant, and D.R. Thomas. 1998. Spring defoliation effects on bluebunch wheatgrass: II. Basal Area. J. Range Manage. 51:526-530.

Clary, W.P., and H.A. Pearson. 1969. Cattle preferences for forage species in northern Arizona. J. Range Manage. 22:114-116.

Collins, S.L., A.K. Knapp, J.M. Briggs, J.M. Blair, and E.M. Steinauer. 1998. Modulation of diversity by grazing and mowing in native tallgrass prairie. Science. 280:745-747.

Costello, D.F. 1964. Range dynamics control - an ecological urgency. P 91-107. *IN*. Grazing in terrestrial and marine environments. Ed. DJ Crisp. Blackwell Scientific Publication. Oxford.

Coughenour, M.B. 1991. Spatial components of plant-herbivore interactions in pastoral, ranching and native ungulate ecosystems. J. Range Manage. 44:530-539.

Coupland, R.T. and T.C. Brayshaw. 1953. The fescue grasslands in Saskatchewan. Ecology. 34:387-405.

Cruz, R., and D. Ganskopp. 1998. Seasonal preferences of steers for prominent northern Great Basin grasses. J. Range Manage. 51:557-565.

Dormaar, J.F. and W.D Willms. 1998. Effects of forty-four years of grazing on fescue grassland soils. J. Range Manage. 51:122-126.

Dormaar, J.F., and W.D. Willms. 1990. Sustainable production from the rough fescue prairie. J. Soil Water Conserv. 45:137-140.

Dormaar, J.F., S. Sandiak, and W.D. Willms. 1989. Vegetation and soil responses to short duration grazing on fescue grasslands. J. Range Manage. 42:252-256.

Dwyer, D.D., P.L. Sims, and L.S. Pope. 1964. Preferences of steers for certain native and introduced forage plants. J. Range Manage. 17:83-85.

Dykersterhuis, E.J. 1949. Condition and management of rangelands based on quantitative ecology. Journ. Range Manage. 2:104-115.

Ellison, L. 1960. Influence of grazing on plant succession of rangelands. Bot. Review. 26:1-75.

Emlen, J.M. 1966. The role of time and energy in food preference. Amer. Natur. 100:611-617.

Evans, M.W. and F.O. Grover. 1940. Developmental morphology of the growing point of the shoot and inflorescence in grasses. J. Agr. Res. 61:481-520.

Flores, E.R., E.A. Laca, T.C. Griggs, and M.W. Demment. 1993. Sward height and vertical morphological differentiation determine cattle bite dimensions. Agron. J. 85:527-532.

Ganskopp, D., B. Myers, S. Lambert, and R. Cruz. 1997. Preferences and behavior of cattle grazing 8 varieties of grasses. J. Range Manage. 50:578-586.

Ganskopp, D., R. Angell, and J. Rose. 1992. Response of cattle to cured reproductive stems in caespitose grass. J. Range Manage. 45:401-404.

Gillen, R.I., W.C. Krueger, and R.F. Miller. 1984. Cattle distribution on mountain rangeland in Northeastern Oregon. J. Range Manage. 37:549-553.

Gillen, R.L., J.A. Eckroat, and F.T. McCollum. 2000. Vegetation response to stocking rate in southern mixed-grass prairie. J. Range Manage. 53:471-478.

Goebel, C.J., and C.W. Cook. 1960. Effect of range condition on plant vigor, production and nutritive value of forage. J. Range Manage. 13:307-313.

Heady, H.F. 1964. Palatability of herbage and animal preference. J. Range Manage. 17:76-82.

Hein, D.G., and S.D. Miller. 1992. Influence of leafy spurge on forage utilization by cattle. J. Range Manage. 45:405-407.

Heitschmidt, R.K., S.L. Dowhower, W.E. Pinchak, and S.K. Canon. 1989. Effects of stocking rate on quantity and quality of available forage in a southern mixed grass prairie. J. Range Manage. 42:468-473.

Hepworth, K.W., P.S. Test, R.H. Hart, J.W. Waggoner Jr., and M.A. Smith. 1991. Grazing systems, stocking rates, and cattle behavior in southeastern Wyoming. J. Range Manage. 44:259-262.

Herbel , C.H., and A.B. Nelson. 1966. Activities of Hereford and Santa Gertrudis cattle on southern New Mexico range. J. Range Manage. 19:173-176.

Hild, A.L., M.G. Karl, M.R. Haferkamp, and R.K. Heitschmidt. 2001. Drought and grazing III: Root dynamics and germinable seed bank. J. Range Manage. 54:292-298.

Holechek, J.L., M. Vavra, J. Skovlin, and W.C. Krueger. 1982. Cattle diets in the Blue Mountains of Oregon, I. Grasslands. J. Range Manage. 35:109-112.

Holechek, J.L, T.J. Berry, and M. Vavra. 1987. Grazing system influences on cattle performance on mountain range. J. Range Manage. 40:55-59.

Howitt, R.E. 1995. How economic incentives for growers can benefit diversity. California Agr. 49(6):28-33.

Hurd, R.M., and F.W. Pond. 1958. Relative preference and productivity of species on summer cattle ranges, Big Horn Mountains, Wyoming. J. Range Manage. 11:109-114.

Johnson, A. 1961. Comparison of lightly grazed and ungrazed range in the fescue grassland of southwestern Alberta. Can. J. Plant Sci. 41:615-622.

Johnson, A. and L.M. Bezeau. 1962. Chemical composition of range forage plants of the *Festuca scabrella* association. Can. J. Plant Sci. 42:105-115.

Johnston, A. 1958. Notes on the distribution of rough fescue. Ecol. 39:536.

Johnston, A. and H.F. Cosby. 1966. Rhizomatous form of *Festuca scabrella*. Can J. Plant Sci. 46:211-212.

Johnston, A. and M.D. MacDonald. 1967. Floral initiation and seed production in *Festuca scabrella* Torr. Can J. Plant Sci. 47:577-583.

Jung, H.J., and L.J. Koong. 1985. Effects of hunger on satiation on diet quality by grazing sheep. J. Range Manage. 38:302-305.

Kie, J.G., and B.B. Boroski. 1996. Cattle distribution, habitats and diets in the Sierra Nevada of California. J. Range Manage. 49:482-488.

King, J.R., M.S. Hill, and W.D. Willms. 1995. Growth response of *Festuca altaica, Festuca hallii* and *Festuca campestris* to temperature. Can J. Bot. 73:1075-1080.

Laca, E.A. 1998. Spatial memory and food searching mechanisms of cattle. J. Range Manage. 51:370-378.

Laca, E.A., L.A. Shipley and E.D. Reid. 2001. Structural anti-quality characteristics of range and pasture plants. J. Range Manage. 54:413-419.

Landau, S.Y., E. Ben-Moshe, A. Shlosberg, M. Bellaiche, and A. Perevolosky. 1999. Conditioned aversion to minimize *Ferula communis* intake by orphaned lambs. J. Range Manage. 52:436-439.

Langer, R.H.M. 1972. How grasses grow. The institute of Biology's. Studies in Biology no. 34. Edward Arnold Limited. London.

Launchbaugh, K.L., F.D. Provenza, and J.A. Pfister. 2001. Herbivore response to anti-quality factors in forages. J. Range Manage. 54:431-440.

Lazo, A., and R.C. Soriguer. 1993. Size-biased foraging behavior in feral cattle. Appl. Anim. Behav. Sci. 36:99-110.

Looman, J. 1983. 111 range and forage plants of the Canadian prairies. Research Branch Agriculture Canada Publication 1751.

Masters, R.A., and R.L. Sheley. 2001. Principles and practices for managing rangeland invasive plants. J. Range Manage. 54:502-517.

Mclean, A. and E.W. Tisdale. 1972. Recovery rate of depleted range sites under protection from grazing. J. Range Manage. 25:178-184.

Mclean, A. and S. Wikeem. 1985. Rough fescue response to season and intensity of defoliation. J. Range Manage. 38:100-102.

McNaughton, S.J. 1985. Ecology of a grazed system: The Serengeti. Ecol. Monogr. 55:259-294.

Mohammad, A.G., C.A. Ferrando, L.W. Murray, R.D. Pieper, and J.D. Wallace. 1996. Season and sex influences on botanical composition of cattle diets in southern New Mexico. J. Range Manage. 49:204-208.

Moisey, D.M. and B.W. Adams. 2002. Annual Summary: Rangeland Benchmark Monitoring Program within the Grassland Natural Region. Public Lands Division. Alberta Sustainable Resource Development. Unpublished Data. Lethbridge, Alberta.

Moorefield, J.G., and H.H. Hopkins. 1951. Grazing habits of cattle in a mixed-prairie pasture. J. Range Manage. 4:151-157.

Moss, E.H. 1944. The prairie and associated vegetation of southwestern Alberta. Can. J. Research. 22:218-229.

Moss, E.H., and J.A. Campbell. 1947. The fescue grasslands of Alberta. Can. J. Res. Sect. C. Bot. Sci. 25:209-227.

Musimba, N.K., R.D. Pieper, J.D. Wallace, and M.L. Galyean. 1987. Influence of watering frequency on forage consumption and steer performance in south eastern Kenya. J. Range Manage. 40:412-415.

Naeth, M.A., A.W. Bailey, D.J. Pluth, D.S. Chanasyk, and R.T. Hardin. 1991. Grazing impacts on litter and soil organic matter in mixed prairie and fescue grassland ecosystems of Alberta. J. Range Manage. 44:7-12.

Okine, E.K., B. Caskey, R. Corbett, B. Berg, and L.A. Goonewardene. 1996. In situ degradabilities of forages selected and not selected by grazing cattle. Can. J. Anim. Sci. 76:459-461.

Olson, B.E., and R.T. Wallander. 2001. Sheep grazing spotted knapweed and Idaho fescue. J. Range Manage. 54:25-30.

Owens, M.K., K. L. Launchbaugh, and J.W. Halloway. 1991. Pasture characteristics affecting spatial distribution of utilization by cattle in mixed brush communities. J. Range Manage. 44:118-123.

O'Reagain, P.J., and E.A. Grau. 1995. Sequence of species selection by cattle and sheep on South African sourveld. J. Range Manage. 48:314-321.

Pavlick, L.E., and J. Looman. 1984. Taxonomy and nomenclature of rough fescues, *Festuca altaica, F.campestris(F.scabrella* var. major),and *F.hallii,* in Canada and the adjacent part of the United States. Can. J. Bot. 62:1739-1749.

Pfeiffer, K.E. and D.C. Hartnett. 1995. Bison selectivity and grazing response of little bluestem in tallgrass prairie. J. Range Manage. 48:26-31.

Pfister, J.A., K.E. Panter, and D.R. Gardner. 1998. Pine needle consumption by cattle during winter in South Dakota. J. Range Manage. 51:551-556.

Pfister, J.A., K.E. Panter, D.R. Gardner, B.L. Stegelmeier, M.H. Ralphs, R.J. Molneux, and S.T. Lee. 2001. Alkaloids as anti-quality factors in plants on western U.S. rangelands. J. Range Manage. 54:447-461.

Pitt, M.D. 1986. Assessment of spring defoliation to improve fall forage quality of bluebunch wheatgrass (*Agropyron spicatum*). J. Range Manage. 39:175-181.

Plice, M.J. 1952. Sugar versus the intuitive choice of foods by livestock. J. Range Manage. 5:69-75.

Popp, J.D., W.P. McCaughey, and R.D.H. Cohen. 1997. Effects of grazing system, stocking rate and season of use on herbage intake and grazing behavior of stocker cattle grazing alfalfa-grass pastures. Can. J. Anim. Sci. 77:677-682.

Popp, J.D., W.P. McCaughey, L.R. Thomas, and R.D.H. Cohen. 1999. Nutrient selection by cattle from grass and grass/legume pastures. Can. J. Anim. Sci. 79:391-395.

Pritz, R.K., K.L. Launchbaugh, and C.A. Taylor Jr. 1997. Effects of breed and dietary experience on juniper consumption by goats. J. Range Manage. 50:600-606.

Provenza, F.D. 1999. Foraging behavior: principles process, and practices. Presented at Alberta Agriculture professional staff workshop. Lethbridge, AB, Canada.

Provenza, F.D., J.A. Pfister, and C.D. Cheney. 1992. Mechanisms of learning diet selection with reference to phytotoxicosis in herbivores. J. Range Manage. 45:36-45.

Pyke, G.H., H.R. Pulliam, and E.L. Charnov. 1977. Optimal foraging: a selective review of theory and tests. Quart. Rev. Biology 52:137-154.

Reese, G.A., R.L. Bayn, and N.E. West. 1980. Evaluation of double sampling estimators of sub alpine herbage production. J. Range Manage. 33:300-306.

Reppert, J.N. 1960. Forage performance and grazing habits of cattle at the Eastern Colorado range station. J. Range Manage. 13:58-65.

Rice, E.L. and R.L. Parenti. 1978. Causes of decreases in productivity in undisturbed tallgrass prairie. Amer. J. Bot. 65:1091-1097.

Roath, L.R, and W.C. Krueger. 1982. Cattle grazing influence on a mountain riparian zone. J. Range Manage. 35:100-103.

Sampson, A.W. 1919. Plant succession in relation to range management. U.S.D.A. Bul. 791.

Sauer, R.H. 1978. The effect of removal on standing dead material on growth of *Agropyron spicatum*. J. Range Manage. 31:121-122.

Scarnecchia, D.L., A.S. Nastis, and J. C. Malechek. 1985. Effects of forage availability on grazing behavior of heifers. J. Range Manage. 38:117-180.

Schwan, H.E., D.J. Hodges, and C.N. Weaver. 1949. Influence of grazing and mulch on forage growth. J. Range Manage. 2:142-148.

Senft, R.L., L.R. Rittenhouse, and R.G. Woodmansee. 1985. Factors influencing patterns of cattle grazing behavior on shortgrass steppe. J. Range Manage. 38:82-87.

Sims, P.L., and R.L. Gillen. 1999. Rangeland and steer responses to grazing in the Southern Plains. J. Range Manage. 52:651-660.

Sinton, H.M. 1980. Effect of burning and mowing on *Festuca hallii*. M.Sc. Thesis University of Alberta. Edmonton, Alberta.

Sinton-Gerling, H., A.W. Bailey, and W.D. Willms. 1995. The effects of burning on *Festuca hallii* in parklands of central Alberta. Can. J. Bot. 73:937-942.

Skinner, R.H., J.D. Hansen, G.L. Hutchinson, and G.E. Shuman. 2002. Response of C_3 and C_4 grasses to supplemental summer precipitation. J. Range Manage. 55:517-522.

Smith, G., J.L. Holechek, and M. Cardenas. 1996. Wildlife numbers on excellent and good condition Chihauhuan desert rangelands: An observation. J. Range Manage. 49:489-493.

Smith, M.A., J.D. Rodgers, J.L. Dodd, and Q.D. Skinner. 1992b. Declining forage availability effects on utilization and community selection by cattle. J. Range Manage. 45:391-395.

Smith, M.A., J.D. Rodgers, J.L. Dodd, and Q.D. Skinner. 1992a. Habitat selection by cattle along an ephemeral channel. J. Range Manage. 45:385-390.

Society for Range Management. 1989. A Glossary of Terms Used in Range Management (3rd Ed.). Society for Range Management, Denver, Colo.

Springfield, H.W. and H.G. Reynolds. 1951. Grazing preferences of cattle for certain reseeding grasses. J. Range Manage. 4:83-87.

Squires, V.R. 1982. Behavior of free-ranging livestock on native grasslands and shrublands. Trop. Grassl. 16:161-169.

Stelljes, K.B., and D. Senft. 1994. Sciences at home on the range. Agr. Res. 1994(Nov):4-8.

Stoddart, L.A., A.D. Smith, and T.W. Box. 1975. Plant Morphology and physiology in relation to range management. P 104-145. *IN*: Range Management 3rd edition. McGraw-Hill, N.Y. 532p.

Stout, D.G., A. McLean, and D.A. Quinton. 1981. Growth and phonological development of rough fescue in interior British Columbia. J. Range Manage. 34:455-459.

Strasia, C.A., M. Thorn, R.W. Rice, and D.R. Smith. 1970. Grazing habits, diet and performance of sheep on alpine ranges. J. Range Manage. 23:201-208.

Strong, W.L., and K.R. Legget. 1981. Ecoregions of Alberta. Alberta Energy and Natural Resources, Resource Evaluation and Planning Division, ENR Tech. Rep. No. T/4.

Strong, W.L., and K.R. Legget. 1992. Ecoregions of Alberta: Volume 1. Alberta Forestry, Lands, and Wildlife, Land Info. Services, Edmonton, Alberta.

Thornton, R.F., and D.J. Minson. 1973. The relationship between apparent retention time in the rumen, voluntary intake, and apparent digestibility of legume and grass diets in sheep. Aust. J. Agr. Res. 24:889-898.

Tilman, D. and J.A. Downing. 1994. Biodiversity and stability in grasslands. Nature 367:363-365.

Tomanek, G.W., E.P. Martin, and F.W. Albertson. 1958. Grazing preference comparisons of six native grasses in the mixed prairie. J. Range Manage. 11:191-193.

Trlica, M.J., and C.W. Cook. 1971. Defoliation effect on carbohydrate reserves of desert species. J. Range Manage. 24:418-425.

Van Wieren, S.E. 1996. Do large herbivores select a diet that maximizes short-term energy intake rate? For. Ecol. Manage. 88:149-156.

Wallis de Vries, M.F., and P. Schippers. 1994. Foraging in a landscape mosaic: Selection for energy and minerals in free-ranging cattle. Oecologia. 100:107-117.

Wallis de Vries, M.F., E.A. Laca, and M.W. Demment. 1999. The importance of scale of patchiness for selectivity in grazing herbivores. Oecologia. 121:355-363.

Walton, P.D. 1983. Production and management of cultivated forages. Reston Publishing Company, Inc. Reston, Virginia.

Westoby, M. 1974. An analysis of diet selection by large herbivores. The Amer. Nat. 108:290-304.

Willms, W.D. 1988a. Response of rough fescue (*Festuca scabrella*) to light, water, temperature, and litter removal, under controlled conditions. Can. J. Bot. 66:429-434.

Willms, W.D. 1988b. Forage production and utilization in various topographic zones of fescue grasslands. Can. J. Anim. Sci. 68:211-223.

Willms, W.D. 1991. Cutting frequency and cutting height effects on rough fescue and Parry oat grass yields. J. Range Manage. 44:82-86.

Willms, W.D. and J. Fraser. 1992. Growth characteristics of rough fescue (*Festuca scabrella* var. *campestris*) after 3 years of repeated harvesting at scheduled frequencies and heights. Can. J. Bot. 70:2125-2129.

Willms, W.D., A.W. Bailey, and A. McLean. 1980. Effect of clipping or burning on some morphological characteristics of *Agropyron spicatum*. Can. J. Bot. 58:2309-2312.

Willms, W.D., and L.M. Rode. 1998. Forage selection by cattle on fescue prairie in summer or winter. J. Range Manage. 51:496-500.

Willms, W.D., B.W. Adams, and J.F. Dormaar. 1996. Seasonal changes of herbage biomass on the fescue prairie. J. Range Manage. 49:100-104.

Willms, W.D., J.F. Dormaar, and G.B. Schaalje. 1988. Stability of grazed patches on rough fescue grasslands. J. Range Manage. 41:503-508.

Willms, W.D., S. Smoliak, and A.W. Bailey. 1986. Herbage production following litter removal on Alberta native grasslands. J. Range Manage. 39:536-539.

Willms, W.D., S. Smoliak, and J.F. Dormaar. 1985. Effects of stocking rate on rough fescue grassland vegetation. J. Range Manage. 38:220-225.

Willms, W.D., S. Smoliak, and J.F. Dormaar. 1990. Vegetation response to time controlled grazing on mixed and fescue prairie. J. Range Manage. 43:513-517.

Wroe, R.A., S. Smoliak, B.W. Adams, W.D. Willms, and M.L. Anderson. 1988. Guide to range condition and stocking rates for Alberta grasslands. Publ. of Alberta Forestry, Lands, and Wildlife, Edmonton, Alberta.

Table 2.1. Examples of forage production and stocking rates for four range condition categories in the foothills fescue prairie.[1]

condition	dominant species	forage production (kg/ha)	stocking rate (ha/Animal Unit Months)
Excellent	rough fescue Parry oat grass Idaho fescue	2250-2700	0.51
Good	rough fescue Parry oat grass Idaho fescue	2000-2800	0.61
Fair	Parry oat grass Idaho fescue rough fescue sedges forb increasers	1500-2800	0.73
Poor	sedges bluegrasses dandelion other invaders	600-2700	1

[1] Adapted from Agriculture and Agri-Food Canada Pub.#1883/E. Foothills Fescue Prairie, Handbook 1.

Table 2.2. Forage qualities of selected grasses in the fescue grasslands as reported by Bezeau and Johnston (1962) or Johnston and Bezeau (1962).

species	growth stage	crude fibre(%)[1]	cellulose (%)[2]	crude protein (%)[1]	digestible protein (%)[2]
Parry oat grass	leaf	30.26 (3.39)[3]	31.7	11.12 (0.93)	4.1
	cured	33.72 (1.16)	38	3.35 (0.65)	0.9
rough fescue	leaf	29.85 (2.83)	33.2	13.68 (4.1)	6.6
	cured	33.39 (1.81)	38.4	4.7 (0.53)	1.5
smooth brome	leaf	28.6 (3.1)	28.2	16.45 (0.65)	10.4
	cured	30.8 (1.7)	35.6	5.75 (2.05)	2.3

[1] Source Johnston and Bezeau (1962)
[2] Source Bezeau and Johnston (1962)
[3] Standard error in parenthesis.

3 Native and Invasive Grass Selection by Cattle Foraging Within Fescue Grasslands

3.1 Introduction

Several studies have indicated that rough fescue (*Festuca campestris* Rydb.) is replaced (McLean and Tisdale 1972, Willms et al. 1985, 1990, 1996) during grazing by species that are less productive and shallower rooted (Walton 1983), but more resistant to grazing (Dormaar and Willms 1990, 1998, Dormaar et al. 1989, Willms et al. 1988, 1996). As long-term grazing intensity increases, rough fescue dominated grasslands deteriorate to a Parry oat grass (*Danthonia parryi* Scribn.) - Kentucky bluegrass (*Poa pratensis,* L.) community, then to a Kentucky bluegrass - upland sedge community (*Carex* species) (Willms et al. 1996). By studying these three plant communities, the authors found that increasingly deteriorated fescue rangeland provided less forage and greater instability of forage production. They also noted that deteriorated communities produce less of their peak production in spring, and lose more dry matter over winter compared to rough fescue dominated grasslands.

Current management appears unable to arrest the advance of invasive plants into rough fescue grasslands. As a result, managers are seeking practical grazing methods to reduce the competitiveness of invasive plants while achieving effective but sustainable utilization of native forages, including rough fescue. Some producers are experimenting with a system of grazing called skim grazing (Adams 2001, Thomas 2001). Under this system, managers apply a light spring grazing in an attempt to utilize rapidly growing "soft" invasive grasses, and then return the cattle later in the season to graze the remaining forage. Soft grasses (e.g. Kentucky bluegrass and smooth brome [*Bromus inermis*, Leyss.]) are those that have relatively less crude fibre when vegetative, are more susceptible to weathering losses, have greater regrowth potential, and shallower root systems compared to "hard" grasses, which include native species such as rough fescue and Parry oat grass (Willms et al. 1996).

The successful use of skim grazing for rough fescue rangeland conservation is dependent on the assumption that cattle will have a decided preference for introduced grass species during spring (i.e. early growing season), a time when these grasses are relatively high in quality. However, this preference is thought to change in favour of the more abundant native species in the fall (i.e. dormant season) when the introduced species have senesced and relative forage quality is more similar among species in fescue grasslands (Johnston and Bezeau 1962, Bezeau and Johnston 1962, Bailey et al. 1996).

Should cattle deliberately select invasive species under skim grazing, this would accomplish several objectives, including (1) conserving rough fescue within the stand, (2) providing a competitive advantage to those native species that do not undergo phytomass loss during the critical spring growth period (Willms 1991), and (3) maintaining invasive species in a vegetative state, thereby increasing their total level of production as well as forage quality later in the summer. Alternatively, if there is no preference or a preference for native species like rough fescue during the spring, the practice of skim grazing could be harmful to the long-term production and sustainability of fescue grasslands, as this species is sensitive to spring defoliation (Willms 1991).

Though apparently sound in theory, little research has examined whether skim grazing can influence plant selection by grazing cattle. Moreover, little information exists on the seasonal preference of cattle for different forage plants, including soft and hard grasses, within areas such as the Fescue Prairie.

This study examined the preferences of cattle grazing native rough fescue rangeland during spring and fall within the Fescue Prairie. The hypothesis tested was that seasonal animal preference for various invasive and native grass species did not differ during either season of grazing. The study focussed on two of the dominant grass species, an invasive plant - Kentucky bluegrass, and a native plant - foothills rough fescue. Parry oat grass and smooth brome, grass species of native and invasive origin, respectively, were of secondary interest.

3.1.1 Objectives

A. Determine if cattle prefer specific native or invasive grasses.

B. Determine if species preference is related to the season of grazing, including spring, fall, and fall regrowth.

3.2 Methods

3.2.1 Site Description

This research was conducted at the Stavely Agriculture and Agri-Food Canada research substation in the Porcupine Hills of southwestern Alberta (50° 11' 30" N, and 113° 53' 30" W; 1,366 meters above sea level). The substation provided facilities, including the grazing pastures, livestock, and herdsman for the project.

The Stavely substation is within the Willow Creek Upland ecodistrict of the Foothills Fescue subregion and Grassland Natural region (Strong and Legget 1992). Moss (1944) and Moss and Campbell (1947) described the Rough Fescue Association vegetation present at the study site. Rough fescue and Parry oat grass are the co-dominant species in this association. Under persistent heavy grazing, vegetation undergoes transformation to predominately Parry oat grass and eventually, becomes a Kentucky bluegrass-upland sedge (*Carex* species) community (Willms et al. 1996).

The regional landform is rolling moraine overlying sandstone (CANSI 1989). The study area was on a loamy range site with a shallow Orthic Black Chernozem (Udic Haploboral) classified in the Dunvagan soil series. The study was conducted on a single ridge with slopes ranging from nearly level (0.5 - 2.5%) to moderate (10 - 15%). Aspect was generally south with elements of southeast and southwest exposure.

Climate data are shown in Figures 3.1 and 3.2. All climate data originated from Agriculture and Agri-Food Canada or Environment Canada weather stations. Long-term average total annual rainfall is 476 mm and the average growing season (April to August) rainfall at the study site is 300 mm. The nearby Claresholm Meadow Creek climate station reported a 30-year average temperature of 5 °C, with an average growing season temperature of 12.9 °C.

3.2.2 Experimental Design

The design for this experiment was a mixed model with three grazing treatments (i.e. spring, fall and fall regrowth) and repeated measures of plant species parameters during both individual six-day grazing periods (i.e. middle and end), and years (i.e. 2000 and 2001). Each grazing treatment was replicated using two pastures each year (Figure 3.3), in total six, one hectare, pastures were utilized. Figure 3.3 illustrates the pasture layout and the randomized application of grazing treatments to individual pastures.

Rough fescue, Kentucky bluegrass, smooth brome, and Parry oat grass were the four plant species identified as being both dominant and important forage species within these grasslands, and were therefore the focus of this study.

3.2.2.1 Grazing Treatments

A preliminary range survey conducted in the spring of 2000 indicated the range condition of pasture A was calculated at 60% of climax, placing it in the "Good" category (Wroe et al. 1988). The suggested stocking rate for the loamy range site in this condition was 0.65 AUM/ac (1.61 AUM/ha) (Wroe et al. 1988). The other pastures had similar vegetation and condition. Plant composition of the various pastures used in this study are provided in Table 3.1, with estimates of herbage production summarized in Table 3.2.

Johnston (1961) recorded historical grazing information for the study area. Prior to 1908, the site was moderately grazed by cattle. From 1908 to 1920, it was moderately grazed by horses, after which the site was used as summer range for cattle until 1943, with heavy grazing during the drought of the 1930's. Since 1944, the area has been infrequently and lightly grazed. Between 1992 and 1994 the pastures used in this project were established and winter grazed by gestating Hereford cows at an average stocking rate of 3.3 AUM/ha. In the year preceding this study (i.e. 1999), grazing occurred with either 1.2 or 1.6 AUM/ha from 15 October to 15 January using cows.

In 2000, two of the six replicate pastures were randomly assigned to one of three grazing treatments: spring only, fall only, or spring and fall grazed. Grazing treatments were not re-randomized in 2001, but rather continued from the year before. In both years, spring pastures were grazed by six cross-bred yearling steers for six days at 0.59 AUM/ac (1.46 AUM/ha), while fall pastures were grazed at 0.74 AUM/ac (1.83 AUM/ha). Steers weighed approximately 360 kg in the spring and 465 kg in the fall. In 2000, grazing occurred in the spring from 24 to 30 May and in the fall from 10 to 16 October. In 2001, grazing occurred in the spring from 29 May to 4 June, and in the fall from 1 to 7 October. Pastures grazed in both seasons received the spring and fall stocking rates described previously. Steers were moved into pastures at noon on the first day of a grazing period, and removed at noon on the sixth and last day. The cattle grazed similar plant communities prior to the start of the trial. Water was hauled to tanks that serviced two pastures at a time by straddling a common fence line. Salt was not provided.

3.2.3 Field Methods and Sampling

3.2.3.1 Pre-grazing

Within each of the pastures, ten, one meter square sampling plots were randomly located during the spring of 2000 for vegetation sampling. This number was increased to 15 in the fall of 2000, and continued through spring and fall of 2001. Following each grazing period, individual plot locations were re-randomized. Plots that landed directly on cattle or truck trails were randomly moved by one metre. Additionally, plots originally situated near the water tank were randomly relocated. Less than 5 percent of the plots required relocation during each year. Quattro Pro 9 was used to randomize plot locations and to map (i.e. graph) the generated coordinates. A flagged grid on the boundary fencelines and mid-pasture marker flags also helped ensure all plots could be relocated as needed.

To facilitate re-sampling, plots were marked with two diagonally placed corner pins and one pin flag. A tag with the plot ID number was placed on the pin at the southeast corner of the plot. A hinged plot frame helped insure consistent placement of the plot. The frame also had quarter meter demarcations (i.e. a grid) that aided in the estimations of vegetation parameters. Pins and pin flags remained in place for the duration of the grazing period and were assumed to have no impact on selection of vegetation by cattle within each plot.

The following data were collected from all plots within each pasture prior to the initiation of each grazing period:

A. Identify all plant species present, lumping immature forbs into an increaser forb (i.e. INCFORB) category.

B. Ocular estimates of fresh (i.e. current years) biomass (green and undried) per species (spp.), in grams.

C. Average height (cm) of current years growth for each species, based on three random measurements.

D. Plot specific comments (e.g. small mammal herbivory).

Reese et al. (1980) concluded that relative dry biomass estimation of a quadrat compared to a reference quadrat, was most adversely affected by low variance in cover and number of species among the quadrats, and high amounts of litter from the previous year. Furthermore they recognized that high litter plots were also the ones with more "difficult-to-estimate" grass species compared to low litter plots dominated by "easy-to-estimate" forbs. Tadmor et al. (1975) found that more homogeneous species composition among independent plots allowed better estimates of biomass. The conditions described by Reese et al. (1980) and Tadmor et al. (1975) were frequently encountered in the current study and attempts to improve the biomass estimates were made by implementing several suggestions made by these researchers.

Reese et al. (1980) suggested that the difference in the influence of species diversity was related to the level of observer experience. Furthermore, it was concluded that training could be used to supplement the natural skills (Tadmor et al. 1975) of the observer to achieve consistent estimations under a variety of conditions. Retraining was recommended when estimates were made at different times of the growing season. Tadmor et al. (1975) found visual "tuning" from photos of previously estimated plots to be useful in the estimation of new plots. Although photos were not available, the technique was adjusted to use actual reference plots which were periodically reviewed during fresh biomass estimations. In addition, double sampling occurred prior to, during, and after biomass estimations were made in individual plots within each pasture. Double samples were taken from an adjacent area, and included the following steps:

A. Self-training of biomass estimation during the days prior to the start of sampling.

B. During sampling, ocular estimates were made of the fresh biomass of each species present in 50 x 50 cm (0.25 m^2) quadrats (in grams).

C. All herbage in each quadrat was clipped, sorted to species, and immediately weighed.

D. For those sampling periods after the spring of 2000, the percent cover of each species was recorded in each quadrat, using the method of Daubenmire (1959).

3.2.3.2 Measurements During and After Grazing

3.2.3.2.1 Species Height-Biomass Data Collection

Field data were collected to develop species specific height-biomass models for later use in the analysis. Randomly selected plants of each species were sampled to represent the size variability of plants. During the spring of 2000, ten plants were collected and amalgamated for each species of interest. These samples were then dissected into five or more even parts (i.e. segments) based on sample average leaf length. Bunch grasses were clipped at the top of the sheath (i.e. minimum stubble height) while rhizomatous species were clipped to ground level. Average persistent sheath height was four centimetres for Parry oat grass and seven centimetres for rough fescue.

In the fall of 2000, an adjustment to the height-biomass field sampling procedures was made. For bunch grasses, ten plants of each species were collected and dissected, as individuals, using the aforementioned method. For rhizomatous species, however, several plants were grouped, which then constituted a "plant sample." This was done to increase the biomass of the sample and better represent the variability of plants within the sward. All ten plant samples of each species were then stratified as described above, dried to a constant mass, and weighed. The latter procedure was repeated in the spring and fall of 2001.

Four separate height-biomass models for each species were needed, one for the spring and fall in each year. These species height-biomass data collection methods approximated those of Willms et al. (1980).

3.2.3.2.2 Estimating Biomass Removal and Plant Selection

Indirect observations and measurements were made within the one metre square plots of each pasture to facilitate estimation of individual plant species selection and utilization by cattle.

The following data were collected on day three of each grazing period and the morning immediately after cattle removal (i.e. day seven):

A. Estimated portion (percent) of plant canopy grazed for each species.

B. Average height of grazed stubble for each species.

3.2.4 Forage Quality Determination

Average nitrogen (N) and acid detergent fibre (ADF) content of each of the four grass species by season and year was determined by analysing the plant samples collected for the height-biomass distribution models (see section 3.2.3.2.1). Samples were pooled by species within a season and year to obtain sufficient material for testing, resulting in one sample per plant species per season per year.

Each sample was ground to pass a one millimetre screen using a Thomas Wiley Intermediate Mill (Arthur H. Thomas Co. Philadelphia, PA.). Samples were re-ground with a UDY Cyclone Mill (UDY Corp., Fort Collins, CO) using a one millimetre screen.

Samples for N analysis were then re-ground with a WIG L BUG grinder (Crescent Dental Manufacturing, Chicago, IL), and analysed in duplicate using the combustion method in a Carlo Erba NA-1500 series one instrument (CE Instruments, Milan, Italy) to determine percent N. Corn stover was used as the standard. Sample percent N was multiplied by 6.25 to determine percent crude protein (CP%).

ADF analysis was done following the methods of Van Soest et al. (1991). Samples were weighed and sealed into prepared and pre-weighed ANKOM technology F57 filter bags. Sealed bags were oven-dried (60° C) and re-weighed to establish dry matter content. ADF was then determined using the ANKOM 200/220 Fibre Analyser (ANKOM Technology, Fairport, NY). Alfalfa was used as the standard. After lab processing, samples were weighed and ADF determined on a dry matter basis. Once the nutrient content of each plant height segment was determined, a weighted average was calculated for the whole plant.

3.3 Data Analysis

Several preliminary analysis steps were necessary before the primary objectives could be addressed. These steps are outlined in Figure 3.4, and explained below.

In general terms, individual plots within each pasture facilitated estimates of available and utilized biomass for each of the four plant species. Changes in plant growth over each six-day grazing period were not accounted for in the estimates, and were assumed to have negligible effects on the determined preferences. A preference index formula, similar to the ratio three technique described by Loehle and Rittenhouse (1982), was used to calculate preference ratings (PR) of cattle for each of the four grass species within each season of grazing and year combination. The final step was an analysis of variance (ANOVA) of the calculated PR values.

Since preliminary data corrections and modelling techniques were used to arrive at the actual PR (section 3.2.3), the reader is cautioned that these methods have the potential to introduce additive error. Furthermore, no sensitivity analysis was completed to determine how variations in the slopes of regression models would affect the final outcome.

ADF and CP data were analysed to test the main effects of season, plant species and their interactions (see section 3.2.4) in order to help interpret the observed preferences.

3.3.1 Available Biomass per Species

Individual plots provided an estimate of initial (i.e. pre-grazing) available fresh (i.e. current years growth) biomass (g/m^2) of each species in each season and year. These estimates were then corrected with models developed from data collected using the double sampling techniques outlined earlier. The correction model statistics (minimum $p<0.01$) are provided in Table 3.3 (see Appendix Figure A.1 for example). On occasion (e.g. < 5%), the estimated values were beyond the maximum and minimum values represented by the double sampling data. It was recognized that employing the derived models to correct these few extreme estimates was not ideal. Given that most of the models were linear, the corrections applied to these extreme values were considered more representative than if no corrections were used.

Corrected plant biomass values were then converted to a dry matter biomass from an estimate of moisture content (unique for each species). Sub-samples within each pasture were averaged, and least square means used in subsequent calculations. For each pasture, the mean biomass (**A**) for each plant species (**i**) and the total biomass of all four species (**B**) were calculated. Finally, the **proportion** of total biomass available for each plant species ($\mathbf{PropBio\_Spp_i}$) was calculated as the fraction of the total biomass available of all species within a given year and pasture (i.e. $\mathbf{PropBio\_Spp_i = A_i/B}$).

Although growth of each of the four species was assumed to be minimal during each grazing period (i.e. assumption A.1. in Figure 3.4), it is likely that any growth would not have been identical among species. Moreover, it is reasonable to assume that had all species continued to grow, the impact on available biomass (and subsequent utilization) estimates would have routinely lowered the modelled biomass values for all four species. In comparison to other sources of error (i.e. imperfections in the double sampling correction and biomass distribution modelling) the impact of this assumption on the final analysis was expected to be a negligible underestimation of PR.

3.3.2 Biomass Distribution Models

Species specific height-biomass models were developed for each season of grazing within each year for a total of 16 models. These models were developed from ungrazed plants that were divided into five or more segments as described in section 3.2.3.2.1. For each plant, the percent of total plant biomass contained in each segment (i.e. 20% of total plant height) was calculated. Cumulative percent height and percent biomass values were then analysed (PROC REG, SAS 1999-2000) to obtain an equation for predicting the anticipated proportion of biomass for a given proportion of plant height. A regression analysis of linear, quadratic and cubic polynomial relationships resulted in acceptable models (minimum $p<0.01$). The best model was chosen based on simplicity and goodness of fit (R^2) as well as the most appropriate representation of the plant species' vertical distribution of biomass for its growth habit (e.g. bunchgrass versus sodgrass). The final biomass distribution model statistics are provided in Table 3.4 (see Appendix Figure A.2 for example).

3.3.3 Remaining and Utilized Biomass at Mid and Post Grazing

Plant initial and mid- (day three) or post- (day six) grazing plant height measurements were used to calculate the proportion of plant height remaining on day three and day six of the grazing period (see Appendix Table A.1 for actual grams utilized within sampling plots). Estimates of remaining proportion of biomass for each species on these days were then made using the height-biomass distribution models outlined previously and converted to actual biomass. Subtraction of the day three or day six estimate of remaining biomass from the corrected initial or mid available biomass respectively, provided an estimate of utilization by day three or six of each grazing period.

The following assumptions were made to facilitate estimation of utilized biomass on day three or six:

1. Growth rates were similar for each species (see Figure 3.4; A.1.).
2. If mean grazed height was less than or equal to zero, then utilization of the available biomass was set at 100 percent (i.e. percent height and biomass remaining were considered zero; see Figure 3.4; A.2). This assumption only impacted rough fescue and Parry oat grass (i.e. the bunch grasses) as models for biomass distribution were developed only for plant material above the persistent sheaths (see section 3.2.3.2.1). If plants were grazed below the average stubble height (i.e. below the measured mean height of the persistent sheaths) it was assumed that all of the modelled plant biomass was utilized.
3. Utilization was considered to be zero or unchanged from the preceding measurement day if the plant was not grazed during the time between successive sampling days (see Figure 3.4; A.3).

A pasture average utilization for each species ($\mathbf{C_i}$), and an overall total pasture utilization (**D**) for all four species was calculated. Finally, the **proportion** of each species utilized (**PropUse_Spp$_i$**) was calculated as a fraction of the total utilization of all species within a year and pasture (i.e. **PropUse_Spp$_i$= C$_i$/D**).

3.3.4 Preference Rating Determination

Ultimately, plant species preferences (**PR**) of cattle were calculated using the following formula:

$\mathbf{PR_i = (PropUse\_Spp_{ip}-PropBio\_Spp_{ip})/(PropUse\_Spp_{ip}+PropBio\_Spp_{ip})}$,

where i=the ith species and p=a given pasture.

Resulting preference values ranged between -1 (complete avoidance of the plant) and +1 (absolute preference or total use by cattle). A preference of zero for a grass species indicated neither preference nor avoidance, but rather utilization in proportion to its availability within the sward.

3.3.5 Preference Rating Analysis of Variance

ANOVA procedures (Proc MIXED, SAS 1999-2000) were used to remove the effects of pasture, species, grazing period (i.e. time), and year from the PR values. Residuals were then tested for normality (Proc Univariate, SAS 1999-2000). The presence of outliers was indicated by stem leaf and normal probability plots, as well as the Shipiro-Wilk test for normality. Two outliers (metre square plots) were removed from the data set, PR values recalculated, and the test for normality rerun, resulting in normal distribution of residuals. The removal of two of the 241 plots had little impact on the actual outcome of the ANOVA analysis but slightly lowered the spring PR of smooth brome, which was only a minor constituent of the plant community.

Nevertheless, this new data set was used in the Proc MIXED procedures described below.

Given that the primary focus of this study was on evaluating animal selection during the critical spring grazing period, data from the spring and fall grazed pastures were analysed separately. This allowed the four spring grazed pastures to be assessed together, increasing the power of the statistical test (i.e. data from the eight pasture by year combinations, four per year, were used to analyse the effect of spring grazing on PR). Preference rating least square means were analysed using ANOVA procedures (Proc MIXED, SAS 1999-2000). The mixed model used was as follows: $PR = \mu + species|time|year + e$, with a random statement identifying pasture as a random variable, and repeated measures in both day of grazing period and year [subject = species(pasture)].

A second ANOVA (Proc MIXED, SAS 1999-2000) evaluated the effect of the three different grazing regimes (tx) (i.e. spring only, fall only and fall regrowth) on the PR for each grass species (spp). To accomplish this, the spring data from the pastures grazed during spring and fall were not used in the second analysis, but rather, was considered a form of conditioning treatment with the potential to affect subsequent animal preferences during fall grazing of the regrowth. The mixed model used was as follows: $PR = \mu + tx|spp|time|year + e$, with a random statement identifying pasture(tx) and spp(pasture X tx) as random variables, and repeated measures of both day of grazing period and year [subject = spp(pasture)].

Where a significant F-value was detected ($p<0.05$), least square means were separated using Tukey's multiple comparisons to control the experiment-wise error.

3.3.6 Forage Quality Analysis

Means of crude protein concentration (%CP) and acid detergent fibre concentration (%ADF) were analysed with ANOVA (Proc GLM, SAS 1999-2000) to test the effect of species, season (spring or fall), and their interactions. Where a significant F-value was detected ($p<0.05$), least square means were separated using Tukey's multiple comparison test to control the experiment-wise error.

3.4 Results and Discussion

3.4.1 Crude Protein and ADF

Van Soest et al. (1991) suggested that neutral detergent fibre (NDF) content rather than acid detergent fibre (ADF) was a better indicator of potential forage intake. In the current study, ADF analysis was completed to arrive at an estimate of relative forage quality and was not required to predict intake. ADF analysis has been a commonly used method among researchers

(Pitt 1986, Adams et al. 1987, Kloppenburg et al. 1995, Fisher et al. 1999).

Percent CP did not vary among plant species or the interaction of species by season ($p>0.05$). Season of sampling significantly affected CP ($p<0.0001$), with fall plants having an average CP of 4.9% versus 14.2% in spring (see Table 3.5).

Percent acid detergent fibre (%ADF) was not affected by the interaction of species on season ($p>0.05$). However, both species ($p<0.001$) and season ($p<0.0001$) affected ADF concentration. Kentucky bluegrass (30.2% ADF) was lower ($p<0.01$) than any other species (see Table 3.6). In contrast, rough fescue and Parry oat grass had the greatest ADF (36.2% and 35.5% respectively). Additionally, ADF concentration in the spring was lower ($p<0.0001$) than in the fall (Table 3.6).

It is important to note that the analysis of forage quality in the current study had only two reps (i.e. through year) and did not test the differences among years or between fall and fall regrowth which may have been significant (Pitt 1986). Popp et al. (1999) also warned that CP and fibre concentrations obtained from clipped samples generally underestimate the actual quality of cattle diets.

3.4.2 Preference Ratings for Plant Species Grazed in Spring

In the analysis of spring grazed treatments (first ANOVA), plant species was the only variable with a significant effect ($p<0.05$) on PR (see Table 3.7). Among species, rough fescue had the greatest numerical PR (PR=+0.15) from cattle, which was significantly different than that of Parry oat grass (PR=-0.38) and smooth brome (PR=-0.55), but was not significantly different from Kentucky bluegrass (PR=-0.04) (see Table 3.8 and Figure 3.5). Cattle PR for rough fescue and Kentucky bluegrass indicated neither preference nor avoidance (i.e. not significantly different from zero, $p=0.18$ and $p=0.72$, respectively). Rough fescue was not avoided despite this species having greater ADF concentrations, as outlined in the previous section.

The species by time interaction was significant at the $p<0.10$ level (see Table 3.7). The PR of Parry oat grass increased ($p=0.01$) from -0.56 to -0.20 from day three to six respectively, while the other species did not change significantly.

Given that PR values are expressed as biomass utilized in proportion to availability, it is unlikely that availability alone (i.e. limited forage quantity) of any species affected the outcome of the analysis. In fact, ocular estimates of canopy cover (see Table 3.1) indicated Kentucky bluegrass had more than twice the abundance of rough fescue (i.e. 32% versus 14%) in spring grazed pastures. Observations that the less common forage grasses such as smooth brome and Parry oat grass (~6% and 10% cover, respectively) were avoided indicated cattle did not sample these species out of novelty.

Previous research indicates Parry oat grass is likely to be one of the most dominant species found on the avoided (Willms 1988b) exposed slopes of foothills rough fescue grassland (Moss and Campbell 1947, Willms et al. 1996). In contrast, Kentucky bluegrass is a dominant species within cattle preferred subirrigated lowlands, particularly in spring (Willms 1988b). Willms (1988b) speculated that relatively early growth and senescence occurs on south-facing slopes compared to other aspects within the native dominated upland topographical zones studied. He concluded that attraction to this early growth did not appear strong enough to draw cattle out of the preferred subirrigated lowlands. The findings of the current study support the observations made by Willms (1988b).

3.4.3 Preference Ratings for Plant Species Grazed in Spring, Fall, or as Fall Regrowth

ANOVA results of the PR among seasonal grazing treatments, (i.e. second ANOVA) are provided in Table 3.9. This analysis resulted in two significant 3-way interactions [i.e. grazing treatment X species X grazing period time (e.g. from the middle to end of grazing period, p=0.04) and species X grazing period time X year (p=0.01)]. There was an additional significant 2-way interaction between grazing treatment and year (p=0.04). The latter interaction, however, was deemed less relevant to the study of animal preferences for forage species. Moreover, given that preferences were relativized among plant species, it was considered inappropriate to compare preferences among effects not containing species as a factor. Thus, the treatment x year interaction was not examined further, but remained in the model as a significant effect (Table 3.9).

3.4.3.1 Grazing Treatment X Species X Time Interaction

In the spring, rough fescue experienced the greatest numeric PR but was not significantly different from zero at any time (p=0.06 day three and p=0.46 day six). The PR of rough fescue was greater than the PR of Kentucky bluegrass (0.25 versus -0.16, respectively) on day three only (see Table 3.10 and Figures 3.6 and 3.7). These results are similar to the results of the spring (alone) analysis reported previously. Given that rough fescue is known to be sensitive to spring grazing (Willms 1991, Maclean and Wikeem 1985), the preference (i.e. day three) or indifferent use (i.e. day six) of this species from Kentucky bluegrass should represent a potential concern to resource managers using skim grazing.

Expression of cattle preference or avoidance for plant species was less pronounced during the spring grazing period than the other two periods, and generally declined over time, from the middle to the end of the grazing period (Figure 3.6. and 3.7). These results are likely due to the greater similarity in forage quality among species in spring compared to the variably senescing biomass of species available in the fall (see Tables 3.4 and 3.5), or an increased appetite of cattle (i.e., willingness to consume anything vegetative). The significance of this finding is that cattle were less discriminating between the 4 grass species in spring and may have found selection of numerous species of nutritional benefit (Herbel and Nelson 1966). Holechek et al. (1982, 1987) also found that the botanical composition of cattle diets was most diverse during the early grazing periods when all species were in early stages of development. In contrast, the majority of the assessed species were being avoided in the fall.

Although Parry oat grass was generally avoided throughout the entire study, within the spring grazed treatment preference for this species increased significantly ($p<0.05$) from -0.65 to -0.16. Parry oat grass had inferior forage quality (Table 3.6), possibly due to the observed persistent dry upper ten centimetres of leaf blade present at all times of the year. It is also possible that even at this relatively light grazing pressure (0.59 AUM/ac), the availability of preferred species was reduced to the point where animals began to select less preferred species (e.g. Emlen 1966) such as Parry oat grass to maintain foraging efficiency.

Overall, Kentucky bluegrass received the greatest PR among the four grasses. Cattle preference for Kentucky bluegrass in the fall and fall regrowth treatments was significantly greater than preference for the other species, a trend evident on both day three and six of the grazing period (see Table 3.10 and Figures 3.6 and 3.7). Senescence of Kentucky bluegrass was observed to be lagging behind the other grasses, and may have led to the relatively greater forage quality of this species (i.e. lower ADF) (Dwyer et al. 1964). Late rainfall in August and September of 2000 (see Figure 3.1) and spring conditioning of vegetation in the regrowth pastures may also have delayed senescence and contributed to the outcome. There was, however, no comparison among years in the current study of either ADF or CP (see section 3.4.1). It is likely that variation in rainfall impacted the observed PR among years by affecting forage quality factors which are known to affect preference (Ganskopp et al. 1997). Greater quality in turn, likely increased cattle preference for Kentucky bluegrass within the fall and fall regrowth pastures.

The other plant species, particularly smooth brome and rough fescue, experienced an increase in PR by cattle during the individual fall grazing periods. Changes in PR, particularly later in a grazing period, may provide evidence that cattle preferences are temporally dynamic, as they begin to switch from Kentucky bluegrass to other grass species. It is also possible that as the availability of greater quality, and locally abundant vegetative Kentucky bluegrass patches declined, foraging efficiency on this species may have fallen to levels below that needed to optimize nutrient intake (Wallis de Vries et al. 1999). O'Reagain and Grau (1995) explained that a basic prediction of optimal foraging theory was that dietary breadth would widen as feed availability declined (Emlen 1966), with feeds being added to the diet in the order of their utility to the animal (Pyke et al. 1977). In keeping with the above findings, it is possible that cattle in the current study were forced to change their grazing behaviour near the end of the fall grazing period, thereby selecting species other than Kentucky bluegrass, including rough fescue and smooth brome. Similarly, Willms (1988b) observed that cattle preferred subirrigated topographical lowlands, which he indicated were dominated by Kentucky bluegrass. Furthermore, he noted that while cattle preferred these areas in the spring, preference for these areas later shifted to upland zones, likely due to depletion of forage in lowlands. Although the study of Willms (1988b) examined preferences at the landscape scale, there were recognizable parallels to the current study, which examined animal preference at the plant scale.

Preference for rough fescue significantly increased from day three to day six within the fall regrowth grazing treatment. The results reported here appear to contrast those of Willms and Rode (1998), who found rough fescue was selected over Kentucky bluegrass during winter. However, the noted increase in rough fescue preference in conjunction with the declining preference for Kentucky bluegrass may indicate that differences in the time of year or other factors such as stocking rate or snow cover may have led to the contrary findings.

The PR for smooth brome was generally negative and did not change significantly during the grazing period (Table 3.10). Field observations were that spring frost often damaged or stressed smooth brome plants. It is possible that these environmental factors affected PR values. Additionally, the PR in the fall-only grazed pastures was significantly (p=0.03) lower than within the fall regrowth pastures on day six (-1.0 versus -0.6, respectively). It is therefore possible that grazing earlier during spring may have resulted in some conditioning of vegetation, which delayed the senescence of smooth brome and enhanced its use in the ensuing fall treatment, particularly late in the grazing period.

Variation in PR expression between the spring and either fall grazed treatments may also be attributed to the actual biomass of forage available at those times. When less forage is available, grazing animals are less selective (Emlen 1966).

Spring grazed pastures had approximately one-third less forage available than fall or fall regrowth pastures (see Table 3.2). The ability to detect utilization (i.e. a proportion of forage removal) was also probably affected by initial forage biomass. More sample plots were grazed in spring when herbage was comparatively less available due to quantity limitations. In the spring of 2000, only 13% (5/40) of the plots sampled remained ungrazed compared to 52% (31/60) in the fall of 2000. The number of sampling plots was increased in the latter in an attempt to overcome this problem.

Although the modelling methods used in the current study were effective in detecting significant differences among relative preferences, they underestimated the actual utilization expected for the pastures (see Appendix Table A.1). Most likely, sampling methods did not accurately account for field variability which was often expressed by patches of very high utilization within larger areas of relatively low utilization. The problem of sampling to estimate actual utilization was also noted by other researchers (Irving 2003). Forage demand was similar between the spring (8.3 kg/day) and fall treatments (8.33 kg/day) (NRC 1996). Average total daily forage requirement of the six steers was approximately 50 kg DM of required forage with another 12.5 kg (25%) of biomass lost due to trampling and manure (ASRD 1990).

3.4.3.2 Species X Time X Year Interaction

Review of the species X time of grazing period X year interaction results indicate that plant species PR were not significantly different (p>0.05) from day three to day six in 2001 (see Table 3.11 and Figure 3.8). Kentucky bluegrass consistently experienced the greatest PR at all sampling times. A stronger preference for Kentucky bluegrass, however, was observed in 2001 than in 2000. In contrast, Parry oat grass was consistently the most avoided species. The PR of both Parry oat grass and rough fescue significantly (p<0.05) increased during grazing periods in 2000, but not in 2001 (Table 3.11).

On day six of 2000, PR values of Kentucky bluegrass and rough fescue were significantly different from those observed in 2001 (p=0.05 and p<0.0001, respectively). In 2001, Kentucky bluegrass received a greater PR than the other three species, all of which were avoided to some extent. On day six in 2000, there was an overall decrease in the expression of preferences, especially for rough fescue and Kentucky bluegrass. As previously discussed, plants with delayed senescence will have better forage quality than those at advanced stages of senescence. Late rainfall in 2000 (see Figure 3.1) likely delayed the senescence of these species and may have contributed to the observed PR values. The effects of these late rains, however, were not expressed by yearly differences in the %ADF and %CP of forage quality.

3.5 Conclusion

This study successfully evaluated relative use among four individual perennial grass species within rough fescue grasslands of SW Alberta using a non-destructive technique. Height-biomass models were successfully used to assess plant biomass before, during, and after grazing. Similar methods were employed by others (Willms and Rode 1998, Willms et al. 1980) and suggest this method can be considered for future projects where non-destructive comparative assessment of forage use is required. The current methods deviated from those previously used by employing visual estimates of available biomass (which were later corrected with double sampling techniques, see section 3.2.3.1). These new methods are particularly useful when studying rhizomatous species where individual plant parameters are less important than the collective, and plants can not be easily distinguished, mapped or measured. Additionally, ocular biomass estimates can be determined more rapidly compared to mapping and measuring individual plants and at a reasonable level of accuracy. In general, the methods used in this study appeared to be adequate for detecting significant differences of PR values among species, as well as their interaction with seasonal grazing treatments. These methods, however, underestimated the actual utilization expected for the pastures (see section 3.4.3.1 and Table A.1) and thus, interpretation should be limited to relative comparisons.

The observed tendency for cattle not to avoid rough fescue in the spring is contrary to that expected based on the current use of skim-grazing practices (i.e. that cattle would select introduced, invasive grasses over native grasses). In general, steers were less discerning among the four focal grass species in the spring compared to when grazing fall pasture or fall regrowth. A similar spring PR given to rough fescue and Kentucky bluegrass suggests that cattle utilize both these species similarly. Moreover, the observed lack of avoidance by cattle for rough fescue in spring indicates the practice of early season skim grazing, even at light to moderate stocking rates, is likely to negatively impact the long-term sustainability of fescue grassland. Continued selection and utilization of actively growing rough fescue will eventually reduce its competitiveness in the plant community (Willms et al. 1985, Willms et al. 1988), and create a niche for invasive species (Ellison 1960, Masters and Sheley 2001). Conversely, Kentucky bluegrass is known to be well-suited to close, repeated and early grazing (Walton 1983). Therefore, spring grazing not only places rough fescue at a competitive disadvantage, but also establishes favourable conditions for Kentucky bluegrass, which amplifies the potential risk to the plant community. Although the successional pathways of plant communities within the fescue grasslands are still under study, there is concern that once a community becomes dominated by Kentucky bluegrass it may have limited potential to revert back to a native species dominated community even with management changes or prolonged rest (Adams 2003).

In contrast, fall and fall regrowth grazing appears to be a practice conducive to the conservation of rough fescue grasslands, while continuing to take advantage of the forage production offered by unsenesced invasive species like Kentucky bluegrass. While the PR for Kentucky bluegrass remained relatively stable over time, preferences for smooth brome and rough fescue increased (i.e. to the end of the grazing period) under fall and fall regrowth grazing. Within a grazing period, temporal changes in PR for individual grass species by cattle indicate preferences were influenced by forage availability and depletion, as well as plant phenological stage (current study, and Beaty and Engel 1980).

The current study was conducted under typical management and average physical rangeland conditions found within fescue grasslands. However forage preference and utilization can be a function of other factors not tested here (e.g. stocking rates). These factors should be considered when interpreting the findings of this study and when developing range management plans.

3.6 Literature Cited

Adams, B.A. 2001. Regional Range Management Specialist. Southeast Region, Alberta Sustainable Resource Development. Personal Communication.

Adams, B.A. 2003. Regional Range Management Specialist. Southeast Region, Alberta Sustainable Resource Development. Personal Communication..

Adams, D.C., R.C. Cochran and P.O. Currie. 1987. Forage maturity effects on rumen fermentation, fluid flow, and intake in grazing steers. J. Range Manage. 40:404-409.

Alberta Sustainable Resource Development, Public Lands. 1990. The animal unit (AU) - adjusting for larger cows. Issue no.5, Publication no. T/207.

Bailey, D.W., J.E. Gross, E.A. Laca, L.R. Rittenhouse, M.B. Coughenour, D.M. Swift, and P.L. Sims. 1996. Mechanisms that result in large herbivore grazing distribution patterns. J. Range Manage. 49:386-400.

Beaty, E.R. and J.L. Engel. 1980. Forage quality measurements and forage research. A review, critique and interpretation. J. Range Manage. 33:49-54.

Bezeau, L.M. and A. Johnston. 1962. *In vitro* digestibility of range forage plants of the *Festuca scabrella* association. Can. J. Plant Sci. 42:692-697.

Canada Soil Inventory. 1989. Soil landscapes of Canada-Alberta. Land Resource Research Centre, Research Branch, Agriculture Canada, Ottawa, Ont. Agric. Can. Publ. 5237/B. 22 pp 1:1 million scale map complied by LRRC Staff in Ottawa and Alberta.

Daubenmire, R. 1959. A canopy-cover method of vegetational analysis. Northwest Science. 33:437-443.

Dormaar, J.F. and W.D Willms. 1998. Effects of forty-four years of grazing on fescue grassland soils. J. Range Manage. 51:122-126.

Dormaar, J.F., and W.D. Willms. 1990. Sustainable production from the rough fescue prairie. J. Soil Water Conserv. 45:137-140.

Dormaar, J.F., S. Smoliak, and W.D. Willms. 1989. Vegetation and soil responses to short duration grazing on fescue grasslands. J. Range Manage. 42:252-256.

Dwyer, D.D., P.L. Sims, and L.S. Pope. 1964. Preferences of steers for certain native and introduced forage plants. J. Range Manage. 17:83-85.

Emlen, J.M. 1966. The role of time and energy in food preference. Amer. Natur. 100:611-617.

Fisher, D.S., H.F. Mayland, and J.C. Burns. 1999. Variation in ruminants' preference for tall fescue hays cut either at sundown or at sunup. J. Anim. Sci. 77:762-768.

Ganskopp, D., B. Myers, S. Lambert, and R. Cruz. 1997. Preferences and behavior of cattle grazing 8 varieties of grasses. J. Range Manage. 50:578-586.

Herbel , C.H., and A.B. Nelson. 1966. Activities of Hereford and Santa Gertrudis cattle on southern New Mexico range. J. Range Manage. 19:173-176.

Holechek, J.L., M. Vavra, J. Skovlin, and W.C. Krueger. 1982. Cattle diets in the Blue Mountains of Oregon, I. Grasslands. J. Range Manage. 35:109-112.

Holechek, J.L, T.J. Berry, and M. Vavra. 1987. Grazing system influences on cattle performance on mountain range. J. Range Manage. 40:55-59.

Irving, B.D. 2003. Technologist. Department of Agriculture, Food, and Nutritional Science, University of Alberta. Personal Communication.

Johnston, A. 1961. Comparison of lightly grazed and ungrazed range in the fescue grassland of southwestern Alberta. Can. J. Plant Sci. 41:615-622.

Johnston, A. and L.M. Bezeau. 1962. Chemical composition of range forage plants of the *Festuca scabrella* association. Can. J. Plant Sci. 42:105-115.

Kloppenburg, P.B., H.E. Kiesling, R.E. Kirksey, and G.B. Donart. 1995. Forage quality, intake, and digestibility of year-long pasture for steers. J. Range Manage. 48:542-548.

Loehle, C., and L.R. Rittenhouse. 1982. An analysis of forage preference indices. J. Range Manage. 35:316-319.

Masters, R.A., and R.L. Sheley. 2001. Principles and practices for managing rangeland invasive plants. J. Range Manage. 54:502-517.

Mclean, A. and E.W. Tisdale. 1972. Recovery rate of depleted range sites under protection from grazing. J. Range Manage. 25:178-184.

McLean, A., and S. Wikeem. 1985. Rough fescue response to season and intensity of defoliation. J. Range Manage. 38:-100-103.

Moss, E.H. 1944. The prairie and associated vegetation of southwestern Alberta. Can. J. Research, C 22:218-229.

Moss, E.H., and J.A. Campbell. 1947. The fescue grasslands of Alberta. Can. J. Res. Sect. C. Bot. Sci. 25:209-227.

National Research Council. 1996. Nutrient requirements of beef cattle. Seveth revised edition. National Academy Press. Washington.

O'Reagain, P.J., and E.A. Grau. 1995. Sequence of species selection by cattle and sheep on South African sourveld. J. Range Manage. 48:314-321.

Pitt, M.D. 1976. Assessment of spring defoliation to inprove fall forage quality of bluebunch wheatgrass (*Agropyron spicatum*). J. Range. Manage. 32:175-181.

Popp, J.D., W.P. McCaughey, L.R. Thomas, and R.D.H. Cohen. 1999. Nutrient selection by cattle from grass and grass/legume pastures. Can. J. Anim. Sci. 79:391-395.

Pyke, G.H., H.R. Pulliam, and E.L. Charnov. 1977. Optimal foraging: a selective review of theory and tests. Quart. Rev. Biology 52:137-154.

Reese, G.A., R.L. Bayn, and N.E. West. 1980. Evaluation of double sampling estimators of sub alpine herbage production. J. Range Manage. 33:300-306.

SAS. 1999-2000. Release 8.1 SAS Institute Inc., Cary, NC.

Strong, W.L., and K.R. Legget. 1992. Ecoregions of Alberta: Volume 1. Alberta Forestry, Lands, and Wildlife, Land Info. Services, Edmonton

Tadmor, N.H., A, Brieghet, I. Noy-Mier, R.W. Benjamin, and E. Eyal. 1975. An evaluation of the calibrated weight-estimate method for measuring production in annual grassland vegetation. J. Range Manage. 28:65-69.

Thomas, L. 2001. "Skim" grazing helps get this ranch ready for drought. Canadian Cattlemen. June/July:8-9.

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Wallis de Vries, M.F., E.A. Laca, and M.W. Demment. 1999. The importance of scale of patchiness for selectivity in grazing herbivores. Oecologia. 121:355-363.

Walton, P.D. 1983. Production and management of cultivated forages. Reston Publishing Company, Inc. Reston, Virginia.

Willms, W.D. 1988b. Forage production and utilization in various topographic zones of fescue grasslands. Can. J. Anim. Sci. 68:211-223.

Willms, W.D. 1991. Cutting frequency and cutting height effects on rough fescue and Parry oat grass yields. J. Range Manage. 44:82-86.

Willms, W.D., A.W. Bailey, and A. McLean. 1980. Effect of clipping or burning on some morphological characteristics of *Agropyron spicatum*. Can. J. Bot. 58:2309-2312.

Willms, W.D., and L.M. Rode. 1998. Forage selection by cattle on fescue prairie in summer or winter. J. Range Manage. 51:496-500.

Willms, W.D., B.W. Adams, and J.F. Dormaar. 1996. Seasonal changes of herbage biomass on the fescue prairie. J. Range Manage. 49:100-104.

Willms, W.D., J.F. Dormaar, and G.B. Schaalje. 1988. Stability of grazed patches on rough fescue grasslands. J. Range Manage. 41:503-508.

Willms, W.D., S. Smoliak, and J.F. Dormaar. 1985. Effects of stocking rate on rough fescue grassland vegetation. J. Range Manage. 38:220-225.

Willms, W.D., S. Smoliak, and J.F. Dormaar. 1990. Vegetation response to time controlled grazing on mixed and fescue prairie. J. Range Manage. 43:513-517.

Wroe, R.A., S. Smoliak, B.W. Adams, W.D. Willms, and M.L. Anderson. 1988. Guide to range condition and stocking rates for Alberta grasslands. Publ. of Alberta Forestry, Lands, and Wildlife, Edmonton, Alberta.

Table 3.1 Ocular estimates of production (uncorrected g/m²) and percent cover (%cov/m²) of species at the Stavely Agriculture and Agri-Food Canada sub-station grazing pastures.

	Pasture A[1]		Pasture B[1]		Pasture C[2]		Pasture D[3]		Pasture E[3]		Pasture F[2]		Average	
Species [4]	g	%cov	g	%cov	g	%cov	g	%cov	g	%cov	g	%cov	g	%cov
Poa prat	31.65	36.66	11.91	17.44	22.99	27.25	27.84	43.52	26.89	29.59	47.94	42.03	28.20	32.75
Fest cam	23.47	10.63	27.59	15.65	30.50	18.31	29.36	19.23	26.10	10.62	30.08	14.45	27.85	14.82
Dant par	13.78	16.58	11.61	8.94	11.34	12.81	8.15	7.30	8.15	7.49	13.12	14.40	11.03	11.25
Brom ine	11.83	4.42	7.00	3.68	9.37	10.98	12.28	8.87	14.81	6.69	3.22	3.32	9.75	6.33
Aste lae	-	-	-	-	9.93	4.69	4.92	2.68	5.74	4.35	1.72	1.01	3.72	2.55
Gali bor	-	-	-	-	-	0.73	-	1.39	3.13	3.04	2.36	1.06	0.92	1.24
Geum tri	3.00	0.50	11.55	-	1.41	-	8.28	3.00	3.94	0.70	3.17	1.01	5.23	1.04
Fest ida	3.16	1.02	3.20	-	1.99	1.69	2.01	-	-	-	2.29	1.06	2.11	0.75
Rosa	-	-	-	-	6.39	-	2.72	1.38	-	-	5.38	2.03	2.42	0.68
Ther rho	-	-	-	-	-	-	-	1.70	-	-	-	1.69	-	0.68
Lath occ	-	-	-	-	-	0.37	-	-	-	2.69	-	-	-	0.61
Pote fru	-	1.61	-	-	-	-	-	-	-	-	-	-	-	0.32
Agro das	3.00	1.53	-	-	-	-	-	-	-	-	-	-	0.50	0.31
Lupinu	-	-	-	-	-	-	-	-	-	-	-	1.35	-	0.27
Solida	-	-	-	-	-	-	-	1.34	-	-	1.8	-	0.30	0.27
Brom pum	-	-	-	-	2.00	1.01	6.14	-	-	-	-	-	1.36	0.20
Lithos	-	-	-	-	-	-	-	-	-	1.00	-	-	-	0.20
Mona fis	-	-	-	-	-	1.00	-	-	-	-	-	-	-	0.20
Agro smi	-	-	-	-	-	-	-	-	-	0.67	-	-	-	0.13
Agro uni	-	0.51	-	-	-	-	-	-	-	-	-	-	-	0.10
Carex	-	0.40	-	-	-	-	-	-	-	-	-	-	-	0.08
Agos gla	5.19	-	-	-	-	-	-	-	2.52	-	-	-	1.29	-
Dote con	8.35	-	5.89	-	-	-	-	-	-	-	-	-	2.37	-
Smel ste	-	-	-	-	-	-	-	-	4.16	-	-	-	0.69	-
Ante ana	2.35	-	2.95	-	-	-	1.22	-	-	-	-	-	1.09	-
Anem pat	-	-	-	-	-	-	-	-	2.54	-	-	-	0.42	-
Antenn	-	-	2.70	-	-	-	-	-	-	-	-	-	0.45	-
Aster	-	-	3.40	-	1.33	-	-	-	-	-	-	-	0.79	-

[1] Estimates made in Spring 2000 and/or Spring 2001.

[2] Estimates made in Fall 2000 and Fall 2001.

[3] Estimates made in Spring and Fall 2000 and 2001.

[4] Species named by 7 letter codes. The first 4 are from the genus name, the last 3 are from the species name. Species with 6 or fewer letters are identified to the genus level only, coded by genus name.

Table 3.2 **Estimates of average production (DM kg/ha) in fescue grassland by season and year of sampling at the Stavely Agriculture and Agri-Food Canada sub-station grazing pastures.**

		- - - 2000 - - -		- - - 2001 - - -		
Season at Study Site	**Species**	**Pasture Mean**	**stderr**	**Pasture Mean**	**stderr**	**Grand Mean**
Spring (May 30)	*Bromus inermis*	55	10.4	36	9.4	46
	Danthonia parryii	75	11.2	26	2.4	51
	Festuca campestris	65	4.4	106	6.2	86
	Poa pratensis	54	14.5	196	24.9	125
	TOTAL[1]	249		364		**307**
Fall	*Bromus inermis*	41	2.5	141	41.4	91
	Danthonia parryii	146	20.9	111	5.0	129
	Festuca campestris	351	0.7	196	3.6	273
	Poa pratensis	495	64.2	418	85.6	457
	TOTAL[1]	1034		866		**950**
Fall Regrowth	*Bromus inermis*	234	14.7	98	23.5	166
	Danthonia parryii	132	11.0	50	0.5	91
	Festuca campestris	288	2.1	237	12.2	262
	Poa pratensis	466	53.2	297	22.4	381
	TOTAL[1]	1119		681		**900**

Site	**Clip Date**	**Mean**		**Clip Date**	**Mean**		
Public Lands Growth Clip[2]	Spring (May 30)	518	72.2	Spring (June 11)	1039	96.1	**779**
	Fall (September 5)	2577	276.2	Fall (August 27)	1663	172.8	**2120**
Public Lands Benchmark[3]	Fall	1608	141.0	Fall	1682	160.2	**1645**

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[1] Corrected ocular estimates only include the production of smooth brome, Parry oat grass, rough fescue, and Kentucky bluegrass.

[2] Estimates made from clips and include all grass and grass-like species. Sustainable Resource Development Public Lands. Unpublished data. These estimates are the best available for total grass and grass-like production on the study site.

[3] Estimates made from clips and include all grass and grass-likes species present on a site protected from grazing for 34 years. Moisey and Adams, 2001.

Table 3.3 Double sampling regression model statistics of actual and predicted biomass of 4 species for 2 years and 2 seasons.[1]

	Pr>F	R^2	b	SE of b	n
	Spring 2000				
Bromus inermis	<0.0001	0.98	0.95	0.04	10
Danthonia parryii	<0.0001	0.94	0.80	0.06	14
Poa pratensis	<0.0001	0.93	0.92	0.09	10
Festuca campestris	<0.0001	0.93	0.78	0.06	12
	Fall 2000				
Bromus inermis	0.005	0.75	1.96	0.46	7
Danthonia parryii	<0.0001	0.95	1.53	0.10	13
Poa pratensis	<0.0001	0.89	1.69	0.14	19
Festuca campestris	<0.0001	0.96	1.39	0.05	18
	Spring 2001				
Bromus inermis	<0.0001	0.97	1.19	0.06	16
Danthonia parryii	<0.0001	0.89	0.79	0.07	17
Poa pratensis	<0.0001	0.93	1.57	0.09	25
Festuca campestris	<0.0001	0.95	0.89	0.04	25
	Fall 2001				
Bromus inermis	<0.0001	0.89	1.83	0.15	21
*Danthonia parryii**	<0.0001	0.94	$1.21x - 0.005x^2$	$0.11x - 0.001x^2$	23
Poa pratensis	<0.0001	0.82	1.52	0.14	25
Festuca campestris	<0.0001	0.95	0.79	0.05	24

[1] Spring was 31 May to 6 June, fall was 28 September to 15 October.

* Quadratic regression equation.

Table 3.4 Biomass distribution regression model statistics for 4 species in each of 2 years and 2 seasons.[1]

	Spring 2000				Fall 2000				Spring 2001				Fall 2001			
	B[2]	D[2]	P[2]	F[2]	B[2]	D[2]	P[2]	F[2]	B[2]	D[2]	P[2]	F[2]	B[2]	D[2]	P[2]	F[2]
Adj. R^2[3]	0.99	0.96	0.99	1.00	0.96	0.97	0.98	0.99	0.98	0.96	0.98	0.96	0.98	0.98	0.97	0.99
a	-11.81	6.80	-1.98	0.95	-11.63	5.70	-3.19	-5.78	-15.05	12.21	-2.21	6.33	-19.52	2.79	3.10	3.95
b	2.61	2.72	2.39	2.32	1.40	2.23	2.47	2.48	2.47	2.30	2.21	1.8	2.327	2.31	2.42	2.27
b^2	-0.02	-0.02	-0.01	-0.01	-0.003	-0.01	-0.02	-0.01	-0.01	-0.01	-0.01	-0.01	-0.011	-0.01	-0.02	-0.01
SE of a	3.10	5.31	4.27	2.10	3.80	2.35	2.14	1.29	2.47	2.07	2.42	2.06	2.2292	1.84	1.89	1.34
SE of b	0.12	0.24	0.16	0.08	0.15	0.093	0.09	0.05	0.09	0.08	0.09	0.08	0.0865	0.07	0.08	0.05
SE of b^2	<0.001	0.002	0.001	<0.001	0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
n	10	11	5	6	51	49	53	53	50	62	50	120	60	60	60	60

[1] Spring is 31 May to 6 June, fall is 28 September to 15 October.

[2] B = *Bromus inermis*, D = *Danthonia parryii*, P = *Poa pratensis* and F = *Festuca campestris*.

[3] Adjusted R^2 was used for models with more than one independent variable. Pr>F = <0.0001 for all models except spring 2000 Poa pratensis which was Pr>F = <0.01.

Table 3.5 Percent crude protein least square means of 4 grass species in fescue grasslands harvested the first week of June or October 2000 and 2001 at the Stavely Agriculture and Agri-Food Canada sub-station. (n=2)

Effect	**Season**	**Species**	**LSM**
Season X Species p=0.14 STDERR=1.58	Fall	*Bromus inermis*	3.38
		Danthonia parryii	3.64
		Festuca campestris	4.09
		Poa pratensis	8.33
	Spring	*Bromus inermis*	14.18
		Danthonia parryii	15.62
		Festuca campestris	14.31
		Poa pratensis	12.55
Species p=0.75 STDERR=1.11	both	*Bromus inermis*	8.78
		Danthonia parryii	9.63
		Festuca campestris	9.20
		Poa pratensis	10.44
Season **p<0.0001** **STDERR=0.78**	Fall		4.86
	Spring		14.17

Table 3.6 Percent acid detergent fibre least square means of 4 grass species in fescue grasslands harvested the first week of June or October 2000 and 2001 at the Stavely Agriculture and Agri-Food Canada sub-station. (n=2)

Effect	Season	Species	LSM[1]
Season X Species p=0.06 STDERR=0.97	Fall	*Bromus inermis*	39.23
		Danthonia parryii	40.92
		Festuca campestris	39.73
		Poa pratensis	33.11
	Spring	*Bromus inermis*	28.15
		Danthonia parryii	30.07
		Festuca campestris	32.58
		Poa pratensis	27.32
Species **p=0.001** **STDERR=0.69**	both	*Bromus inermis*	33.69b
		Danthonia parryii	35.49bc
		Festuca campestris	36.16c
		Poa pratensis	30.21a
Season **p<0.0001** **STDERR=0.48**	Fall		38.26
	Spring		29.53

[1] Within effect and column, LSMs followed by different letters are significantly different (p<0.05).

Table 3.7 ANOVA results of the repeated measures analysis of preference ratings for 4 grass species during spring grazing at 2 times of the grazing period during each of 2 years. Mixed model: Preference = spp|time|year.

Effect	Num DF	Den DF	F value	Pr > F
Species (spp)	3	16.3	9.25	**0.0008**
Time	1	13.4	0.40	0.5377
Spp X Time	3	13.4	3.35	0.0515
Year	1	15.6	0.01	0.9387
Spp X Year	3	15.6	0.73	0.5469
Time X Year	1	14.1	0.01	0.9147
Spp X Time X Year	3	14.1	2.16	0.1381

Table 3.8 Least square means of preference ratings by cattle for the 4 dominant grasses grazed in the spring of 2000 and 2001 in rough fescue grasslands near Stavely, Alberta.

Species	**LSM**	**PR > t[2]**
Festuca campestris	0.15 a[1]	0.18
Poa pratensis	-0.04 a	0.72
Bromus inermis	-0.55 b	<0.0001
Danthonia parryii	-0.38 b	0.002
STDERR	0.10	

[1] Means followed by different letters differ significantly (p<0.05).

[2] T-test results; means are significantly different from zero if t<0.05.

Table 3.9 ANOVA results of the repeated measures analysis of cattle preference ratings for 4 grass species in 3 grazing treatments at 2 times in each of 2 years. Mixed model: Preference = tx|spp|time|year.

Effects	**Num DF**	**Den DF**	**F value**	**Pr > F**
Grazing Treatment (Tx)	2	2.84	9.71	0.0538
Species (Spp)	3	8.92	55.12	<0.0001
Tx X Spp	6	8.92	9.65	0.0018
Time	1	11.8	6.70	0.0240
Tx X Time	2	11.8	1.65	0.2325
Spp X Time	3	11.8	2.10	0.1537
Tx X Spp X Time	6	11.8	3.35	**0.0360**
Year	1	12	1.12	0.3111
Tx X Year	2	12	4.51	**0.0346**
Spp X Year	3	12	4.23	0.0294
Tx X Spp X Year	6	12	2.10	0.1285
Time X Year	1	12	8.75	0.0120
Tx X Time X Year	2	12	1.71	0.2228
Spp X Time X Year	3	12	5.93	**0.0102**
Tx X Spp X Time X Year	6	12	1.73	0.1980

Table 3.10 Least square means of preference ratings by cattle for 4 grasses within each of 3 grazing treatments applied over 6 days in rough fescue grasslands near Stavely, Alberta, as determined by repeated measures analysis of day 3 and 6 data.

Grazing Treatment[1]	Species	Day 3	Day 6	Day SD[3]
Spring	*Bromus inermis*	-0.57 a[2]	-0.65 a	
	Danthonia parryii	-0.65 a	-0.16 b	*
	Festuca campestris	0.25 c	0.10 b	
	Poa pratensis	-0.16 b	-0.08 b	
Fall	*Bromus inermis*	-0.93 ab	-1.00 a	
	Danthonia parryii	-1.00 a	-1.00 a	
	Festuca campestris	-0.62 b	-0.40 b	
	Poa pratensis	0.33 c	0.27 c	
Fall Regrowth	*Bromus inermis*	-0.84 a	-0.60 a	
	Danthonia parryii	-1.00 a	-0.86 a	
	Festuca campestris	-0.96 a	-0.51 a	*
	Poa pratensis	0.40 b	0.32 b	

[1] Treatments applied spring or fall of 2000 and 2001. Standard error of LSM = 0.12.

[2] Within grazing treatment and day, means followed by different letters differ significantly ($p<0.05$).

[3] An asterisk indicates a significant change in PR between days ($p<0.05$), within a grazing treatment and species.

Table 3.11 Least square means of preference ratings for each of 4 grasses in rough fescue grasslands near Stavely, Alberta, subjected to 6 days of grazing[1]. Analysis was with repeated measures on day 3 and 6 in each of the 2 years.

Year	Species	Day 3	Day 6	Day SD[3]
2000	*Bromus inermis*	-0.83 a[2]	-0.68 a	
	Danthonia parryii	-0.86 a	-0.62 a	*
	Festuca campestris	-0.46 b	0.04 b	*
	Poa pratensis	0.13 c	0.05 b	
2001	*Bromus inermis*	-0.73 a	-0.81 a	
	Danthonia parryii	-0.91 a	-0.72 a	
	Festuca campestris	-0.43 b	-0.59 a	
	Poa pratensis	0.25 c	0.30 b	

[1] Grazed during the spring or fall of 2000 (SE=0.10) and 2001 (SE=0.09).

[2] Within a year and day, column means followed by different letters differ significantly ($p<0.05$).

[3] An asterisk indicates a significant change in PR between days ($p<0.05$), within a year and species.

Figure 3.1 Precipitation for the Agriculture and Agri-Food Canada sub-station near Stavely, AB.

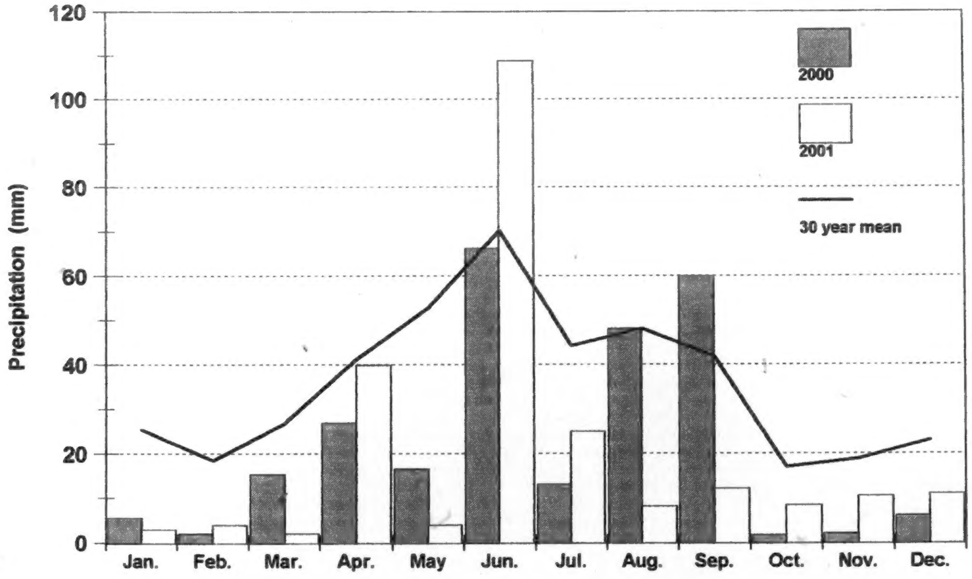


Figure 3.2 Temperatures for the Agriculture and Agri-Food Canada sub-station near Stavely, AB.

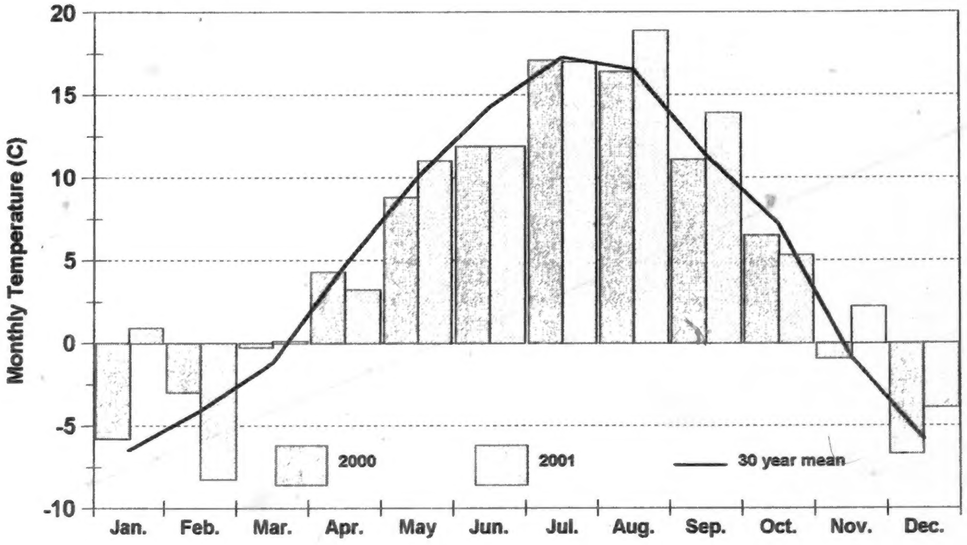


Figure 3.3 Layout of grazing pastures and timing of grazing applied within the study. (Gates marked with "X" and water with a bar.)

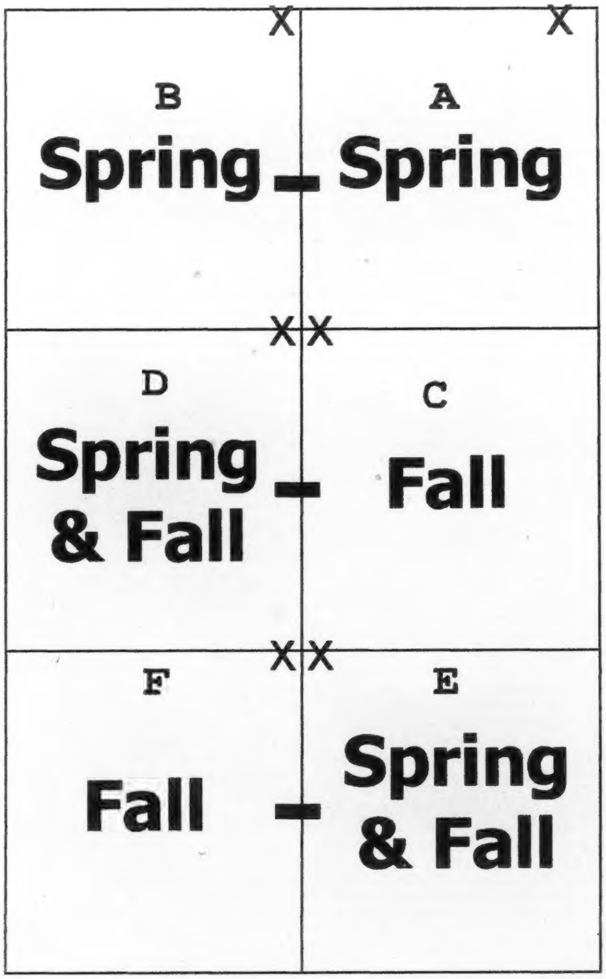

X
X
B
A
Spring
Spring
X X
D
C
Spring & Fall
Fall
X X
F
E
Fall
Spring & Fall

Figure 3.4 Analysis flow chart (section 3.3)

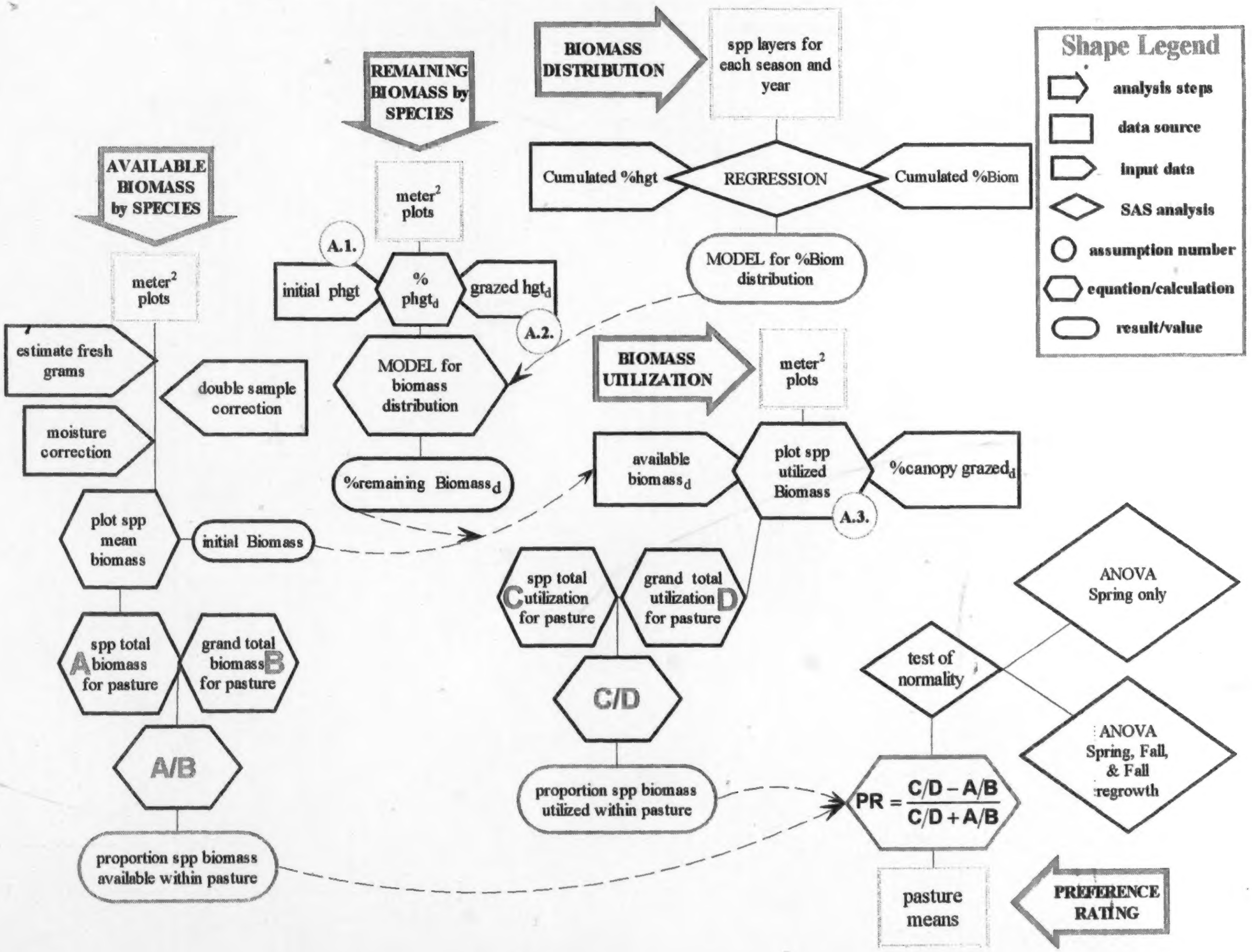

AVAILABLE BIOMASS by SPECIES
meter^2 plots
estimate fresh grams
double sample correction
moisture correction
plot spp mean biomass
initial Biomass
A spp total biomass for pasture
grand total biomass B for pasture
A/B
proportion spp biomass available within pasture
REMAINING BIOMASS by SPECIES
meter^2 plots
A.1.
initial phgt
% phgt$_d$
grazed hgt$_d$
A.2.
MODEL for biomass distribution
%remaining Biomass$_d$
BIOMASS DISTRIBUTION
spp layers for each season and year
Cumulated %hgt
REGRESSION
Cumulated %Biom
MODEL for %Biom distribution
BIOMASS UTILIZATION
meter^2 plots
available biomass$_d$
plot spp utilized Biomass
%canopy grazed$_d$
A.3.
C spp total utilization for pasture
grand total utilization D for pasture
C/D
proportion spp biomass utilized within pasture
$PR = \frac{C/D - A/B}{C/D + A/B}$
test of normality
ANOVA Spring only
ANOVA Spring, Fall, & Fall regrowth
pasture means
PREFERENCE RATING
Shape Legend
analysis steps
data source
input data
SAS analysis
assumption number
equation/calculation
result/value

Figure 3.5 Cattle preference ratings of spring grazed species in fescue grasslands near Stavely, AB. Columns marked with the same letters are not significantly different.

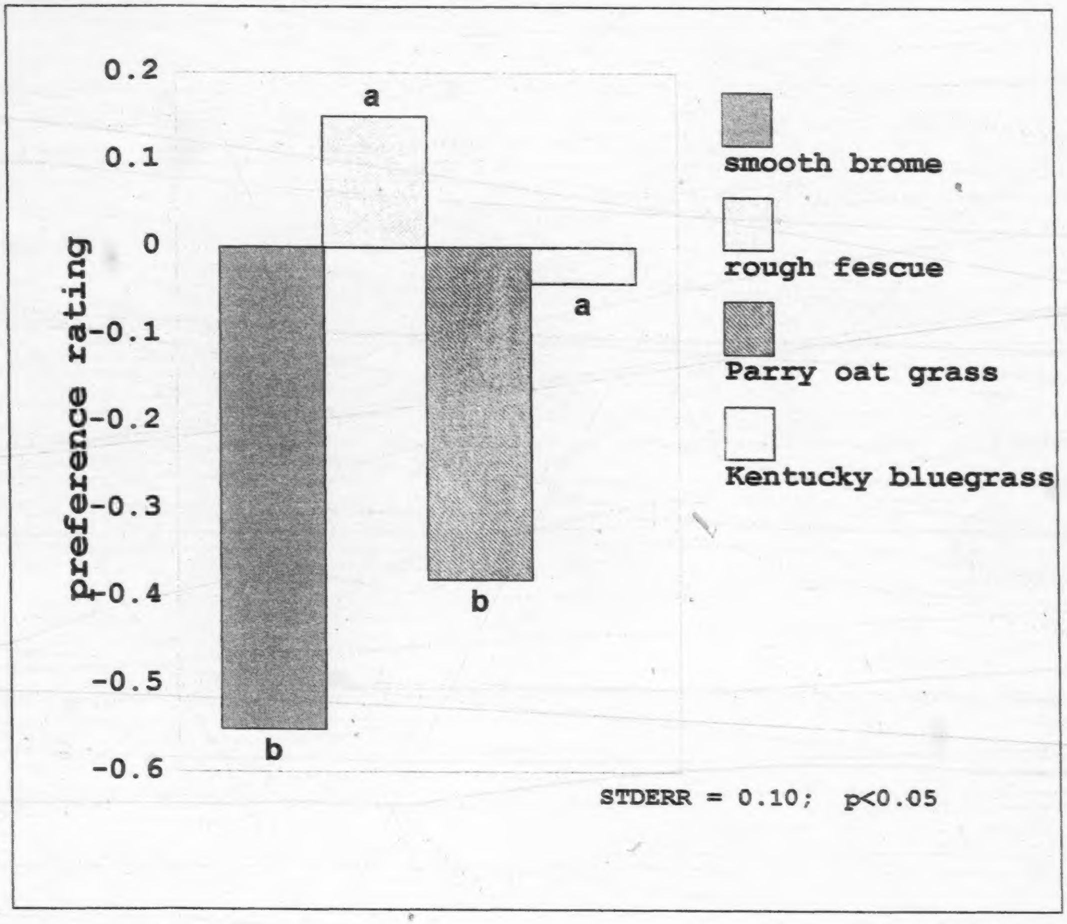


Figure 3.6 Cattle preference ratings of spring, fall, and fall regrowth grazed species after 3 days in fescue grasslands near Stavely, AB. Within season, columns marked with the same letters are not significantly different.

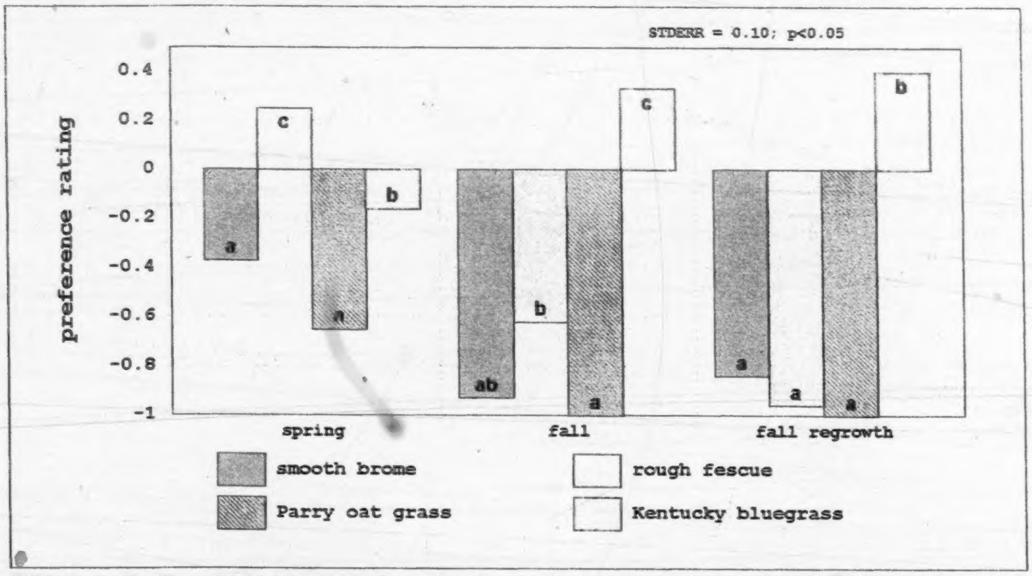


Figure 3.7 Cattle preference ratings of spring, fall, and fall regrowth grazed species after 6 days in fescue grasslands near Stavely, AB. Within a season, columns marked with the same letters are not significantly different.

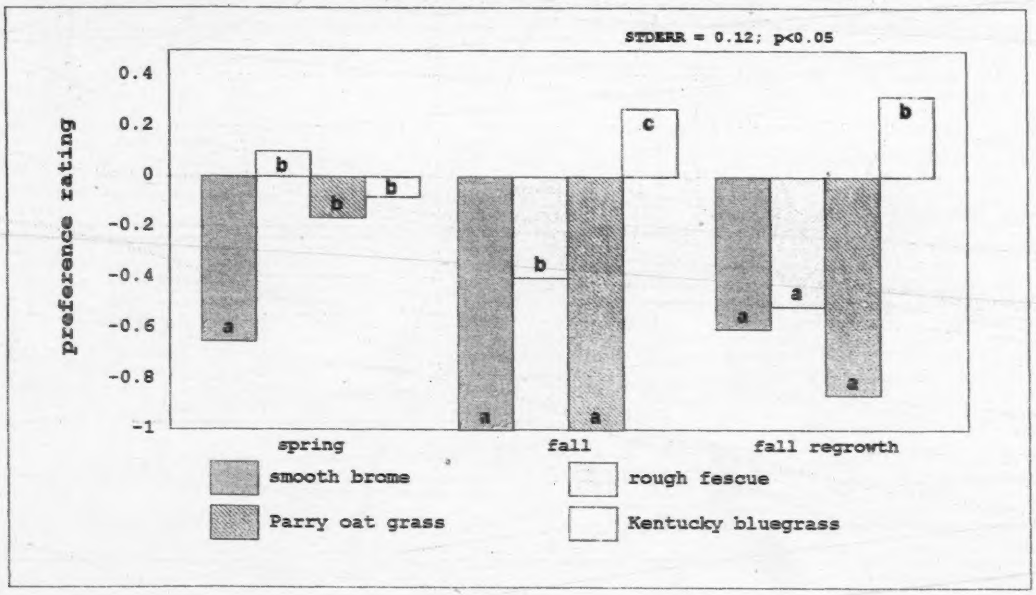
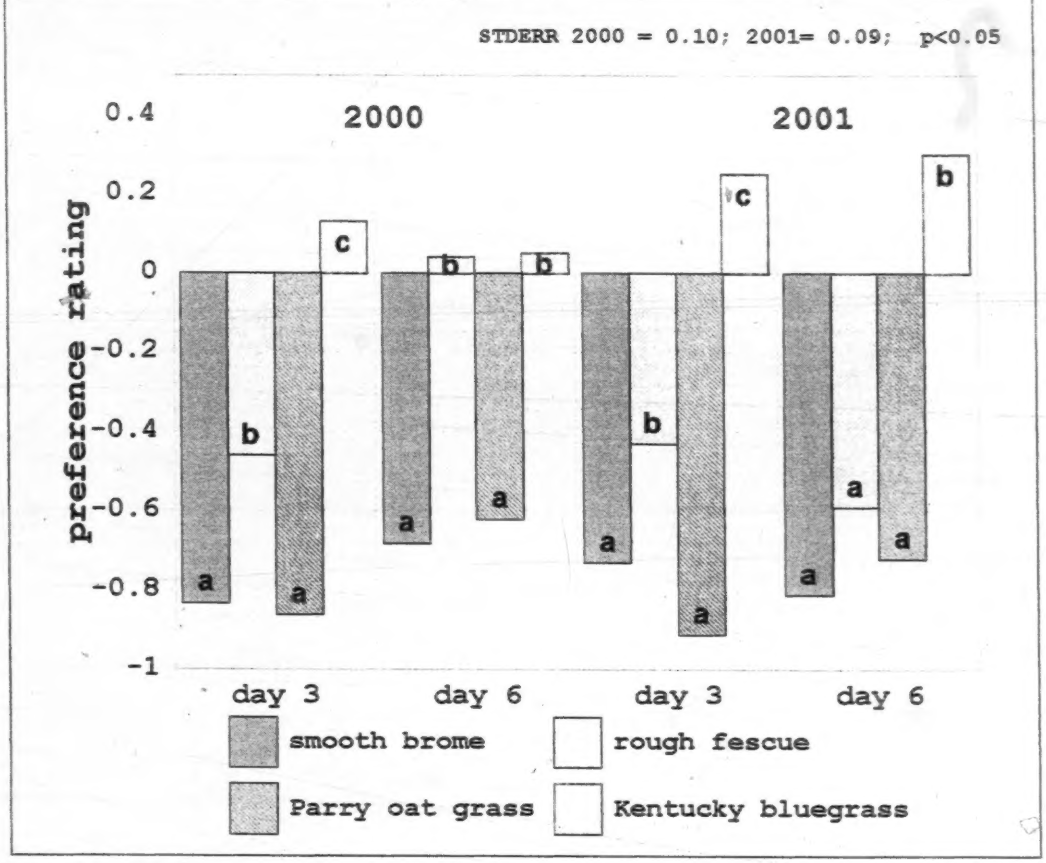


Figure 3.8 Cattle preference ratings for 4 plant species subjected to 6 days of grazing with repeated measures on day 3 and 6 and each of 2 years in fescue grasslands near Stavely, AB. Within a year and a day, columns marked with the same letters are not significantly different.



4 Effects of Standing Litter Removal on Subsequent Cattle Utilization of Rough Fescue

4.1 Introduction

For the purpose of this study, standing litter was considered to be the senesced aboveground growth still attached to the plant. Given a choice, livestock select plants with relatively little or no standing litter (Bakker et al. 1984, Pfeiffer and Hartnett 1995). Furthermore, within an individual plant, it has been observed that standing litter poses a physical barrier to cattle accessing new growth, which can lead to economically significant losses (e.g. Romo et al. 1997). Ranchers commonly refer to these litter-protected plants as wolf plants, or if abundant, the stand of grass is considered to be 'rank'.

Patches of non-uniform utilization in a pasture result when the stocking rate or animal density is too low to apply uniform grazing pressure to the forage resource (Spedding 1971). Areas of overgrazing and under-grazing are a consequence of this uneven foraging. Under-grazed areas accumulate excessive litter, while over-grazed areas have relatively little litter. Naeth et al. (1991) found that heavy and/or early grazing had a larger negative impact on litter levels than light and/or late season grazing. Season-long grazing systems tend to result in the most uneven grazing pressure and perpetuate the development of vegetation patchiness (Willms et al. 1988). Willms et al. (1988)

found that grazed patches within the Fescue Prairie were dominated by grazing resistant species such as Kentucky bluegrass (*Poa pratensis* L.), and that these patches were spatially stable in both the short and long-term. They also concluded that the persistence of over-grazed patches led to long-term effects including changes in species composition, potential soil degradation, and generally a decline in range condition.

Where total residual carryover (i.e. including both attached litter and loose litter) is abundant, plants may be 'protected' from grazing (Laca et al. 2001) during the sensitive spring period by litter that is unattractive to grazing animals. Conversely, previously heavily defoliated plants may be preferred due to the absence of a litter barrier. The potential impact on unprotected plants is a gradual loss of vigor, and eventual disappearance from the plant community.

This research investigated the barrier effects associated with various amounts of standing litter on subsequent rough fescue (*Festuca campestris* Rydb.) selection and utilization by cattle. The hypothesis tested was that standing litter is a greater deterrent to cattle grazing, thereby reducing the extent of utilization of rough fescue.

4.1.1 Objectives

A. Determine the effect of fall clipping (i.e. simulated grazing) and associated litter removal on subsequent rough fescue selection by cattle in spring.

B. Determine the effect of various fall clipping (i.e. simulated grazing) intensities on the level of subsequent utilization in rough fescue plants by cattle during spring.

4.2 Methods and Techniques

4.2.1 Site Description

This research was conducted at the Stavely Agriculture and Agri-Food Canada research substation in the Porcupine Hills of southwestern Alberta (50° 11' 30" N, and 113° 53' 30" W; 1,366 meters above sea level). The substation provided facilities, including the grazing pastures, livestock, and herdsman for the project.

The Stavely substation is situated within the Willow Creek Upland ecodistrict of the Foothills Fescue subregion and Grassland Natural region (Strong and Legget 1992). Moss (1944) and Moss and Campbell (1947) provide a description of the rough fescue vegetation association present at the study site, which is considered representative of the dominant range type for the region (Strong and Legget 1992). Rough fescue and Parry oat grass (*Danthonia parryi* Scribn.) are the co-dominant species in this association. Under persistent heavy grazing, these communities undergo transformation to a Parry oat grass dominated site and eventually become a Kentucky bluegrass-upland sedge (*Carex* species) community (Willms et al. 1996).

The regional landform at the station is rolling clay-loam moraine overlying sandstone (CANSI 1989). The study itself was conducted on a single ridge with slopes near level (0.5 - 2.5%). Aspect was generally south with elements of southeast and southwest exposure. The soil was a loamy, shallow Orthic Black Chernozem (Udic Haploboral) classified in the Dunvagan soil series.

The long-term average total annual rainfall for the station is 476 mm and the average growing season (April to August, inclusive) rainfall at the study site is 300 mm (Figure 4.1). The nearby Claresholm Meadow Creek climate station reported a 30-year average temperature of 5 °C with an average growing season temperature of 12.9 °C (Figure 4.2). All climate data originated from either local Agriculture and Agri-Food Canada or regional Environment Canada weather stations.

4.2.2 Experimental Design

The design for this experiment was a mixed model with four levels of standing litter removal (i.e. clipping) treatments and ten replications. Repeated measures of rough fescue parameters were taken throughout the grazing period. Three, one hectare, native pastures were utilized in this study. Figure 4.3 illustrates the layout of pastures, the type of grazing treatment applied, and the location of studied plants. A completely randomized block design was applied to a belt transect in each of the two grazed pastures (A and B). The experiment was repeated in the same year (pastures A and B) and included an ungrazed control (pasture C).

A preliminary range survey was conducted in the spring of 2000. Range condition of pasture A was calculated at 60.1 percent placing it in the "Good" category (Wroe et al. 1988). The suggested stocking rate for the loamy site in this condition was 0.65 AUM/ac (1.61 AUM/ha) (Wroe et al. 1988, Dormaar and Willms 1990). The other pastures had similar vegetation and condition. Site specific species lists and composition of the pastures used in this study are provided in Table 4.1.

Both Johnston (1961) and Willms and Rode (1998) recorded historical grazing information. Prior to 1908, the site was moderately grazed by cattle. Throughout 1908 to 1920, it was moderate grazed by horses. From 1920 to 1943 the site was used as summer range for cattle and received heavy grazing during the drought of the 1930's. The area has been infrequently, but lightly grazed since 1944. Between 1992 and 1994, the pastures used in this project were established and winter grazed by pregnant Hereford cows at an average stocking rate of 3.3 AUM/ha. In 1999, grazing with either 1.2 or 1.6 AUM/ha occurred from 15 October to 15 January using cows. In 2000 and 2001, two or three concurrent studies (see section 3) occurred in six pastures, one of which was the current study.

In the fall of 2000, pastures A and B were randomly selected from the four available spring grazed pastures as the study areas for the grazed treatment of the trial. Pasture C was randomly selected from the two available fall grazed pastures to serve as an ungrazed control. Pastures A and B were grazed by six cross bred steers (approximate spring weight of 360 kg or 795 lbs) for six days at 0.59 AUM/ac (1.46 AUM/ha) from 31 May to 4 June in spring 2001. Pasture C was only grazed in the fall of 2000 (and 2001 for the previously mentioned concurrent study) at a stocking rate of 0.74 AUM/ac (1.83 AUM/ha). The cattle grazed similar plant communities prior to the start of the trial. Water was hauled to a tank that serviced the two pastures at once. Salt was not provided.

4.2.3 Field Methods

4.2.3.1 Pre-grazing

Within moderately grazed areas, in each of pastures A and B, a permanent belt transect was randomly placed. Transect ends were permanently marked with metal posts. At ten locations along each of the two transects, four rough fescue plants were selected to create ten replicate blocks. The purpose of blocking was to present the grazing animal with the choice of all four treatments within a relatively small area. The actual area of each block varied and was dependent on the proximity of suitable plants. In order to prevent excessive variation among the initial plants, 'suitable' plants were those with an average circumference of approximately 60-65 cm based on a visual assessment. The resulting block sizes ranged from approximately one to three square metres.

Within each block, one of four treatments was randomly assigned to each rough fescue plant. Plant heights were determined by firmly placing a ruler in the centre of the plant crown. The treatments applied were: control (no standing litter removal); litter removal above 14 cm (i.e. leaving 14 cm of litter on and around the base of the plant); litter removal above 7 cm; and litter removal above 2.5 cm (i.e. equates to 95% litter removal). The untreated control plants were marked by placing a metal 'U' pin within 15 cm of their base to distinguish them from other (untreated) plants within the block. The detailed location of each plant was measured from the centre-line of the transect and mapped to ensure relocation.

A third set of 40 plants were selected in pasture C to serve as an ungrazed control. These plants were randomly assigned litter removal treatments as previously described and were used for evaluating plant responses to the clipping treatments themselves, modelling growth and biomass distribution, and assessing plant nutrient responses.

The following data were collected in November 2000 from all 120 experimental plants:

A. Average leaf height of current annual growth at the centre of the crown.

B. Plant basal circumference measured at the soil surface.

C. For the ten plants clipped at 2.5 cm within the ungrazed control pasture (i.e. pasture C), the plant material was removed in three segments, which included above 14 cm, 7-14 cm, and 2.5-7 cm. Each segment was individually bagged, oven dried at 60° C, and weighed.

Removal of the plant material was accomplished using hand shears and, where necessary, a saw. During sampling in November 2000, there was about 20 cm of snow on the ground. Displaced snow during the application of treatments was replaced onto plants after all measurements were complete.

The average leaf height of current annual growth above the crown centre on all plants was measured prior to grazing (28 May 2001). At that time, one of the 2.5 cm treated plants was observed to be destroyed by pocket gopher activity.

4.2.3.2 During and Post-Grazing

Pastures A and B were subsequently spring grazed for six days from 29 May to 4 June 2001. Six yearling steers were moved into the pastures at noon on the first day and out at noon on the last. Table 4.2 summarizes the time-lines of the study by calender, growing, grazing, and measurement days.

Observations on the experimental plants were made on the mornings of 31 May (measurement day one abbreviated to mday1), 1 June (mday2), 3 June (mday3), 4 June (mday4) and 6 June (mday5). The latter date coincided with two days after the cessation of grazing. Observations included:

A. Ocular estimates of the proportion of plant canopy area affected by grazing.

B. Average leaf height of grazed stubble above the crown.

C. Ungrazed plant height (in pasture C only) on mday2, mday4, and mday5 for the purpose of estimating growth responses to clipping treatments and to adjust estimates of available and utilized biomass.

Harvesting of current annual growth from all experimental plants was delayed one day (from 5 June to 6 June) due to rain.

Plants in pasture C were clipped in five segments (as described below) to provide a means to model biomass and nutrient distribution in relation to plant height (see sections 4.3.2.4 and 4.3.3). The average height of each plant was recorded and divided by five to establish five uniform height segments. These segments were then sequentially removed starting from the top and moving down to approximately 2.5 cm (the crown stubble below 2.5 cm could not be removed). Each sample was bagged and oven-dried at 60^0 C. Samples were then sorted into current annual growth and litter portions and weighed. (Note: the standing litter fraction was only collected from the unclipped ungrazed control plants in pasture C). Due to the time consuming nature of sorting live and dead material, larger samples were sub-sampled, sorted into the two fractions and the total weight for each fraction then determined from the sorted sub-sample weights. All other experimental plants in pastures A and B were clipped in one segment to 2.5 cm, sorted, dried and weighed as described above.

4.2.4 Forage Quality Determination

The vertical distribution of nitrogen (N) and acid detergent fibre (ADF) within individual rough fescue plants was determined by analysing the incremental harvested segments of each ungrazed plant in pasture C (see section 4.2.3.2). The two highest segments of current annual growth of each plant were pooled to obtain sufficient material for testing (i.e. resulting in four samples per plant). Similarly, the top three segments of litter had to be pooled for the same reason (i.e. resulting in three samples per plant).

Each sample was ground to pass a one millimetre screen using a Thomas Wiley Intermediate Mill (Arthur H. Thomas Co. Philadelphia, PA.). Samples were re-ground with a UDY Cyclone Mill (UDY Corp., Fort Collins, CO) using a one millimetre screen.

Samples for N analysis were then re-ground with a WIG L BUG grinder (Crescent Dental Manufacturing, Chicago, IL), and analysed in duplicate using the combustion method in a Carlo Erba NA-1500 series one instrument (CE Instruments, Milan, Italy) to determine percent N. Corn stover was used as the standard. Sample percent N was multiplied by 6.25 to determine percent crude protein (CP%).

ADF analysis was done following the methods of Van Soest et al. (1991). Samples were weighed and sealed into prepared and pre-weighed ANKOM technology F57 filter bags. Sealed bags were oven-dried (60^0 C) and re-weighed to establish dry matter content. ADF was then determined using the ANKOM 200/220 Fibre Analyser (ANKOM Technology, Fairport, NY). Alfalfa was used as the standard. After lab processing, samples were weighed and ADF determined on a dry matter basis.

4.3 Data Analysis

Data analysis included more than one pasture, with ten replications of each treatment nested within each pasture. The analysis for objective A (selection) was comparatively simple relative to that for objective B (utilization), and is provided in section 4.3.1.

Several preliminary calculations and analysis steps were necessary before objective B could be addressed. These are explained in section 4.3.2 and shown in Figure 4.4. In general terms, utilization of experimental rough fescue plants was estimated non-destructively with height-biomass models. These models were established from similar plants growing in the absence of grazing (i.e. pasture C plants). Modelled measures of utilization of plants in pastures A and B, in turn, were used to test the hypotheses that the influence of previous defoliation (i.e. conditioning treatments applied in the fall) on subsequent spring use.

In addition, and as part of objective B, an analysis of the relationship between remaining stubble height (i.e. standing litter height) and grazed height was completed. The relationship was hypothesized to provide a management tool capable of predicting the expected utilization for an average spring rough fescue stubble height under light to moderate grazing pressure.

Nutrient data were also analysed (see section 4.3.3) in order to explore the effect of previous clipping treatment on nutrient distribution, and gain insight into utilization results.

4.3.1 Analysis of Selection (Objective A)

Data from the two grazed pastures (i.e. pasture A and B) were first checked to see that selection trends were similar among pastures, and then pooled to facilitate Chi-square analysis. Chi-square tests of nonparametric accumulative plant selection data were initially analysed in 4x2 contingency tables. Data from each day of sampling were tested against the hypothesis that plants of all clipping treatments were selected equally ($p>0.05$). Post-hoc treatment means separation was done using 2x2 contingency tables. Experiment-wise error was controlled by adjusting the comparison-wise alpha according to the Dunn-Sidak procedure (Carr and Lee 2002). This adjustment is considered an improvement on the Bonferroni procedure for unequal sample sizes, and was slightly less conservative (SAS 1999-2000). The formula for the Dunn-Sidak adjustment was: $a_c = 1 -(1- a_e)^{1/N}$, where a_c was Sidak's comparison-wise alpha (adjusted confidence level); a_e is the desired experiment-wise error rate; and N was the number of possible comparisons. Where necessary, significance was determined using Fisher's exact test (Steel et al. 1997) when the count of accumulative plants selected (i.e. totals) in all rows and columns was less than 15.

In addition, regrazed plant count data were analysed using Chi-square analysis in 4x2 contingency tables testing the hypothesis that plants of all four clipping treatments were equally re-selected (i.e. regrazed).

4.3.2 Analysis for Utilization (Objective B)

4.3.2.1 Growth Assessment

Regression analysis of changes in plant height within pasture C against day of sampling resulted in a strong linear relationship ($p=0.006$, $R^2=0.99$) with the following equation: Height = -0.15 + 0.44(day) (see Appendix Figure A.3). This equation was then used to predict the expected height of each grazed plant for each measurement period (i.e. day) from the initial plant height had grazing not occurred during the study period. Although it is likely that all plants in all pastures did not grow at the same rate due to site, genetic, or vigor differences, it was assumed that random sampling would account for this variability.

Predicted height (cm) for each of the measurement days one through five, was referred to as: phgt1, phgt2, phgt3, phgt4 and phgt5, respectively. The model formulas for calculating these variables were:

phgt1 = initial height + 1.18 cm (represents three days of growth);

phgt2 = initial height + 1.35 cm (represents four days of growth);

phgt3 = initial height + 2.5 cm (represents six days of growth);

phgt4 = initial height + 2.95 cm (represents seven days of growth);

phgt5 = initial height + 3.95 cm (represents nine days of growth).

Basal area was tested as a possible covariate to improve the prediction of modelled height further, but was not significant and therefore, not included in the final model.

The effects of pasture, fall clipping treatment, and their interaction, were tested for their effects on spring growth, including initial height and volume, as well as growth during the grazing period and cumulative growth using MANOVA [Proc GLM (and random statement), SAS 1999-2000]. Where a significant pasture by clipping treatment interaction resulted, additional MANOVA tests were run on individual pastures to test the main effect of the clipping treatment alone. If a significant ($p<0.05$) F-value was detected, least square means were separated using Tukey's multiple comparison test to control the experiment-wise error.

4.3.2.2 Canopy Density Assessment

Using the pasture C experimental plants, plant volume for mday 5 was calculated using a cylindrical formula (i.e. Volume_5 = Basal area X hgt_5). This process assumed that canopy cover was cylindrical, an assumption that has been accepted by other researchers for a bunch-grass species (e.g. Willms et al. 1980). A biomass density (mg/cm^3) parameter was then calculated for each plant using the following formula: Density_5 = harvested total plant biomass_5 / volume_5. In order to proceed with other steps in the analysis and to ensure no bias, it was necessary to test if final plant density was affected by clipping treatment. ANOVA (Proc GLM, Steel et al. 1997) found no significant effect ($p=0.78$) of the previous fall clipping treatment on biomass density in pasture C plants. Mean fescue plant canopy density was 1.99 mg/cm^3, a value which was subsequently used as a constant to estimate the available biomass of plants within the grazed treatments. Additionally, no significant relationship was found between fescue plant canopy density and initial plant size ($p>0.10$), including initial height, basal area, or canopy volume.

4.3.2.3 Available Biomass Determination

Estimates of available biomass volume, assuming no grazing, were made for each experimental plant in pastures A and B using the calculated predicted height ($phgt_d$), which included an adjustment for growth (see Section 4.3.2.1), and its basal area. This calculation was done for each day of measurement (subscript 'd') using the following formula: $Volume_d$ = Basal area X $phgt_d$. Predicted total biomass (Twt_d) for each plant was then calculated using the density constant of 1.99 mg/cm^3 and $volume_d$ (i.e. Twt_d = 1.99 X $volume_d$). These methods were similar to those used by Willms et al. (1980).

4.3.2.4 Biomass Distribution Model

Biomass distribution models were developed from the harvested biomass of the 40 ungrazed plants in pasture C as there was no significant effect ($p>0.05$) of clipping treatment on biomass distribution within the plant. These plants were divided into five segments as described in section 4.2.3.2. First, the percent of total plant biomass contained in each segment (i.e. 20% of total plant height) was calculated. Cumulative percent height and biomass values were then analysed (Proc REG, SAS 1999-2000) to obtain an equation for predicting percent biomass for a given height percentile. Regression analysis of linear, quadratic and cubic polynomial relationships resulted in three acceptable models. However the quadratic, which best represented the physical shape of rough fescue plants, was also the simplest, had the best fit ($p<0.0001$, $R^2 = 0.98$), and had significant variable components ($p<0.0001$). Thus, the quadratic model (see Appendix Figure A.4), was used to predict percent biomass as follows:

$$\% \text{ biom} = -19.46 + (2.40 \times \% \text{ hgt}) + (-0.01 \times (\% \text{ hgt})^2).$$

An initial scatter plot of the percent height versus percent biomass, as well as an ANOVA test isolating the clipping treatment effect on biomass distribution, both failed to indicate a difference ($p>0.05$) among clipping treatments. Thus, data from the 40 ungrazed plants were pooled to derive the final biomass distribution model, which ensured more of the unknown plant variability could be incorporated without compromising the model with clipping treatment effects.

To test the accuracy of the modelling methods used, actual residual plant biomass and predicted residual biomass values were compared. A regression of 119 predicted biomass (dependent) values against actual biomass (independent) as well as initial plant volume (independent covariate) resulted in a highly significant linear model ($p<0.0001$), with an adjusted R^2 value of 0.97 and no intercept effect (i.e. the intercept was not significant). However, a paired t-test of the difference between predicted and actual plant biomass found a significant difference ($p<0.0001$). Further investigation by regression (Proc REG, SAS 1999-2000) of the differences between predicted and actual biomass, and the difference of actual density from the applied constant (i.e. 1.99 mg/cm^3), revealed that variation in plant density [biomass/(Basal area X hgt)] from the applied mean of 1.99 mg/cm^3 caused predicted plant biomass to be too high if basal area was below average or too low if the basal area was above average. Nevertheless, the strong fit of the model made it a useful tool for predicting biomass availability.

4.3.2.5 *Remaining Biomass Determination*

The remaining proportion of predicted height (% $phgt_d$) of each plant in pasture A and B at each measurement day was calculated as follows: (grazed $height_d$ X 100)/$phgt_d$, where d = measurement day. Estimates of remaining biomass (% $rbiom_d$) were then made using the biomass distribution.

4.3.2.6 *Utilization Determination and Analysis of Variance*

The following assumptions were made to facilitate estimation of final utilized biomass per plant on any measurement day:

1. If actual height was greater than the predicted height, percent height was limited to 100 (Figure 4.4; A.1.).
2. If percent height equalled 100, then percent biomass was set to 100 (Figure 4.4; A.2.).
3. Where a plant had visibly not been defoliated during the time period between two successive measurement days, utilization was considered zero or unchanged from the preceding measurement day (Figure 4.4; A.3.).

Overall utilization was estimated as the portion of total plant biomass removed by grazing. The following formula provides the estimate of percent biomass utilized: $utilz_d$ = (total $biom_d$ - [% $biom_d$ / 100 X total $biom_d$]) X (pct_d/100), where pct_d is the ocular assessment of the proportion of the plant's canopy area affected by grazing up to a measurement day (i.e. $mday_i$). Basal area, or other covariates related to plant size were not required because utilization values were expressed as proportions. Furthermore, the influence of plant size and growth were eliminated so that comparisons of utilization changes could be made over the grazing period and expressed as percent plant biomass removed.

Prior to the final analysis of variance, all utilization data were tested for homogeneity of variance (Levene's test Proc GLM, SAS 1999-2000) and normality (Shapiro-Wilks tests, Proc Univariate, SAS 1999-2000). Percent utilized biomass data were transformed using a Freeman Tukey arcsin transformation (Zar 1999) to meet the requirements of normality. Transformed data were then analysed using the MIXED procedure of SAS (1999-2000) to test for the main effects of pasture, clipping treatment and their interaction. Initial analysis indicated a significant pasture by clipping treatment interaction. As a result, individual pastures were tested for the main effect of clipping treatment using ANOVA (Proc GLM, SAS 1999-2000). Where a significant F-value was detected ($p<0.05$), least square means were separated using Tukey's multiple comparison test to control the experiment-wise error.

MANOVA procedures (Proc GLM SAS 1999-2000, Steel et al. 1997, Entz, T. 2002) were used to test, and in turn, simplify (i.e. non-significant parameters were dropped from the model), polynomial models describing the relationship of grazed height and clipped litter stubble height. The best model was chosen based on simplicity and goodness of fit (R^2).

4.3.3 Forage Quality Analysis

Means of %CP and %ADF were taken from each plant segment within a clipping treatment for analysis. Nutrient data from these current growth height segments were then analysed with ANOVA (Proc MIXED, SAS 1999-2000) to test for the effect of clipping treatment, plant height segment and their interaction. Nutrient data from the litter component were analysed for segment effect using Proc MIXED (SAS 1999-2000). A repeated statement (SAS 1999-2000, Entz 2002) was included in the Proc Mixed procedure to account for autocorrelation among segments of the same plant. Where interactions were significant ($p<0.05$), further testing (ANOVA) of the segment effect was done within a clipping treatment to identify trends. When a significant F-value was detected ($p <0.05$), least square means were separated using Tukey's multiple comparison test to control the experiment-wise error.

4.4 Results and Discussion

4.4.1 Pretreatment Tests

Although basal area was not significantly different among the clipping treatments (p=0.28), it was significantly different between pastures (p=0.01)(Table 4.3). Moreover, the consistent absence of a covariate effect in the various analyses performed suggested that plants responded similarly to treatment, regardless of their initial basal area and overall size. Nevertheless, the analysis included the pastures as a treatment variable to account for variation in plant size among pastures.

4.4.2 Effect of Clipping Treatment on Plant Growth

Culley et al. (1933) discussed the value and limitations of using clipping to simulate grazing. Two of the noted limitations may be applicable to the current study: 1) the fact that clipping cuts plant material uniformly but livestock mainly pull and break stems and leaves at variable heights; and 2) litter and its associated benefits were removed from the site through clipping. In the current study, clipping occurred on rigid and matured plant material and resulted in a rather rough edge, weathering over winter. However, it was still at a uniform clipping height. Given that the dormant season application of treatments resulted in no live phytomass removal, the impacts on the plant would be limited to those that result from the litter removal itself. The intent of the current study was to physically remove standing litter according to treatment design, which was necessarily accompanied by minor trampling by researchers.

Tests of clipping on initial (i.e. pre-grazing) mean plant height and volume indicated a significant effect of the pasture by clipping treatment interaction ($p=0.03$ and $p=0.002$, respectively). Further analysis was therefore done on individual pastures to test the main effect of clipping treatment (Table 4.4). Significant clipping treatment effects were found in all pastures on initial height and volume.

In all pastures, the most severe litter removal treatment (i.e. clipping to 2.5 cm), resulted in a significant reduction ($p<0.05$) in live plant height the following spring. Intensively defoliated plants ranged from 5 to 8 cm shorter compared to those undefoliated. In pasture B, the 7 cm treatment also significantly affected initial fescue plant height, reducing it by 4 cm compared to the control plants.

The results for initial plant canopy volume followed a pattern similar to those of initial height (Table 4.4). In pastures A and B, the 2.5 cm treated plants had significantly less initial volume than the control (i.e. undefoliated) plants. This change is not surprising given that height and basal area measures were incorporated into the determination of canopy volume.

Tests were also conducted on ungrazed plants from pasture C for residual clipping treatment effects on the rate of growth of rough fescue during the spring sampling period. Table 4.5 contains a summary of actual height and cumulative height growth. After the initial height comparison, plants defoliated at 2.5 cm continued to be significantly shorter than those within the other treatments throughout the sampling period.

Although cumulative height growth tended to be lower on intensively defoliated fescue plants toward the end of the sampling period, it was not significantly affected ($p>0.05$) by defoliation treatment during the study period (Table 4.5). Similarly results were found by Sinton (1980) for *F. hallii* following mowing, as treated plants started growth earlier but growth rates were reduced compared to the control. Notably, the total growth of *F. hallii* was 2.9 cm over eight days starting 18 June (Sinton 1980), while in the current study, *F. campestris* grew 3 cm over seven days starting 28 May (Table 4.5). Mowing of *F. hallii* in the spring to an average height of 3.6 cm also caused a significant reduction of regrowth compared to the un-mowed control (Sinton-Gerling et al. 1994).

Contrary to these findings, Ellison (1960) indicated that clipping stimulated the elongation of tops and that cumulative height growth was often greater for clipped versus unclipped plants in greenhouse studies. Differences in the conditions and timing of clipping treatments among the former and the current study likely contributed to the differing results. The lack of difference among defoliation treatments in this study suggested no adjustment for growth was required to provide an unbiased estimate of treatment effect on utilization. Nevertheless, adjustments for growth were applied because they were deemed to provide a closer approximation of actual utilization.

Ungrazed plants in pasture C were also tested for the effect of clipping treatment on total biomass production at the end of the spring sampling period. Analysis of variance indicated no biomass difference existed among plants exposed to various defoliation treatments (p=0.27, Table 4.6). These results imply that even though more intensively fall defoliated plants were shorter, they produced similar biomass. Beaty and Engel (1980) and Willms et al. (1980) suggested that forage yield was likely related to the size and number of tillers. Indeed, several studies have reported no effect of fall clipping treatments on subsequent biomass production (Willms and Fraser 1992, Bogen 2001, McLean and Wikeem 1985, Sinton 1980) although increases in tiller numbers occurred relative to the controls (Willms and Fraser 1992, Bogen 2001, Sinton 1980). Some researchers have attributed the increased tillering to greater photosynthetically active radiation (PAR) near the plant crown (Willms 1988a, Langer 1972).

Initial parameters (i.e. height, basal area, and canopy volume) of the control plants were tested for their relationship to final plant canopy (i.e. biomass) density as a means to identify possible covariates. Regression analysis showed no significant relationship between final canopy density and initial plant height (p=0.10), basal area (p=0.18) or canopy volume (p=0.65). Moreover, clipping treatment did not significantly affect plant density (p=0.78), which remained near a mean of 1.99 mg/cm^3. This value was therefore used as the constant (without a covariate) to estimate available and utilized biomass for plants within the grazed pastures.

4.4.3 Plant Selection

Chi-square analysis of the fall clipping treatment effects on subsequent plant selection in spring indicated that previous defoliation affected the likelihood of spring use (Table 4.7). On the second day of grazing (i.e. 31 May), there were significantly fewer unclipped rough fescue plants selected relative to those previously clipped.

These results provide evidence that fescue plants with standing litter removed are more likely to be defoliated by cattle compared to plants with high litter levels. They also indicate that only a light defoliation (e.g. to 14 cm) in fall is required to 'condition' plants, or increase the likelihood of subsequent use. Finally, the probability of defoliation also appeared to increase with exposure to herbivory. Later in the spring period, cattle appeared to show indiscriminate selection among all experimental plants indicating selection uniformity increased. Thus, the mere presence of standing litter does not appear to prevent a rough fescue plant from being grazed.

O'Reagain and Grau (1995) determined that animals grazed 80 to 100 percent of the tillers on preferred and intermediately preferred species before the avoided species were used. Other researchers have found that plants with the presence of standing litter (Pfeiffer and Hartnett 1995), reproductive stems (Flores et al. 1993, Ganskopp et al. 1992), or high litter accumulation (Willms and Rode 1998) were less likely to be grazed and had lower levels of utilization. In the current study, the level of litter removal (i.e. clipping treatment) had no effect ($p>0.30$) on whether cattle grazed or regrazed a given rough fescue plant three or six days into the grazing period. This result indicates that the barrier effect of litter has limited impact on plant selection by cattle. Eighteen percent of plants sampled were regrazed at least once after three days and 48% after six days of grazing. Furthermore, 96% of the studied plants were selected at least once by the end of the six-day grazing period.

4.4.4 Utilization

Rough fescue utilization increased as litter removal treatments imposed the previous fall became increasingly severe (Table 4.8). This trend was apparent among all defoliation treatments by day 2.5 of the spring grazing period in pasture B, but took 4.5 days of grazing to achieve in pasture A (Table 4.8). Ganskopp and Rose (1992) found that *Agropyron desertorum* [(Fischer ex Link) Schultes] plants with basal areas of 65 to 104 cm^2 (i.e. mid sized plants) were selected more often than any other size classes. Similar findings were reported by Pfeiffer and Hartnett (1995) working with *Schizachyrium scoparium* (Mich.) Nash (average basal areas of mid sized plants were 100 to 150 cm^2). As previously reported, pasture A had significantly smaller basal areas than pasture B. It is therefore possible, that plant size may have affected initial plant selection. Nevertheless, patterns of plant utilization were similar at the end of the six day trial. In both grazed pastures, the 2.5 cm clip treatment, which removed approximately 95% of the plant standing litter, was utilized most heavily the following spring.

Many researchers have determined that utilization of rough fescue in the critical growing season is detrimental to its vigor, survival, and productivity (Willms et al. 1985, McLean and Wikeem 1985, Willms and Rode 1998). However, for many ranchers and resource managers, grazing during the critical spring period is often necessary. McLean and Wikeem (1985) and Bogen (2001) reported that clipping rough fescue earlier in the spring may have less impact on plant death, leaf height, tiller numbers and yield per plant than late spring grazing. Maintaining adequate heights of spring standing litter appeared to act as a barrier to grazing, essentially protecting the current plant growth from being excessively utilized in this critical period. These results suggest the impact of grazing fescue grasslands may be reduced if both the timing and level of utilization are closely monitored.

Regression analysis of stubble height(i.e. $stubhgt_i$, independent) with grazing height (i.e. $gzhgt_i$, dependent) revealed a significant quadratic relationship for all four days of measurement ($mday_i$) ($p<0.0001$), with R^2 values ranging from 0.66 for day one to 0.78 for day four. ANOVA procedures (Proc GLM, Steel et al. 1997) using simplified models resulted in highly significant parameters in all cases. For days one and two, the effect of pasture was also significant, leading to separate models for each pasture. The lack of any significant pasture by clipping treatment interaction on days three and four, however, indicated that the quadratic functions representing the relationship were parallel, with significantly different intercepts (see Figure 4.5). Thus, single predictive models were developed for both pastures combined on each of these days. The resulting equations were as follows for each measurement day:

mday1 (pasture A) $gzhgt = 7.51\ cm + (1.00 \times stubhgt) + (-0.01 \times stubhgt^2)$

mday1 (pasture B) $gzhgt = 4.22\ cm + (1.00 \times stubhgt) + (-0.01 \times stubhgt^2)$

mday2 (pasture A) $gzhgt = 6.08\ cm + (1.03 \times stubhgt) + (-0.02 \times stubhgt^2)$

mday2 (pasture B) $gzhgt = 4.47\ cm + (1.03 \times stubhgt) + (-0.02 \times stubhgt^2)$

mday3 $gzhgt = 3.56\ cm + (1.28 \times stubhgt) + (-0.02 \times stubhgt^2)$

mday4 $gzhgt = 4.06\ cm + (1.27 \times stubhgt) + (-0.02 \times stubhgt^2)$

4.4.5 Forage Quality and Nutrient Distribution

Levels of acid detergent fibre (%ADF) content in the standing litter were not significantly different among vertical plant segments of the undefoliated plants during the spring of 2001 (p=0.21; Table 4.9). Similarly, clipping treatment alone had no significant effect (p=0.41) on the quality of current years' growth, although the interaction of clipping treatment by segment was significant for this parameter (p=0.03). Despite this, least square means separation of the interaction indicated no significant differences (i.e. p>0.05) existed (analyses not shown) when comparing the same segment among treatments (see Table 4.9 for data). Further investigation revealed that within each clipping treatment, all segments were significantly different from each another (p<0.0001; Table 4.9). The results also indicated that %ADF progressively increased from the top moving to the lowest plant segments. The top segment had an average of 4 percent less ADF than the lowest segment. Because the trend of changing ADF levels within live vegetation was similar among all clipping treatments, ADF values were considered to have little potential influence on observed levels of plant selection or utilization by cattle in this study.

Crude protein content (%CP) of residual litter was not significantly different among the vertical segments sampled from fescue plants in spring (p=0.31, Table 4.10). Similarly, for current years' growth, both clipping treatment and the interaction of clipping with segment were not significant ($p>0.05$). As might be expected, however, the segment effect was significant ($p<0.0001$), and revealed that %CP increased as plant vertical height segment increased (Table 4.10). Upper segments had an average of 1.9 %CP more than the segment directly below. The trend of decreasing %CP to the lowest segments remained for all clipping treatments, and therefore, would once again be considered to have very little influence on plant selection or utilization.

Using the forage quality parameters measured, the quality of current rough fescue growth clearly declined nearing the base of the plant. Similar results were noted by Willms et al. (1981) studying bluebunch wheat grass. The overall low quality of standing litter (also noted by Beaty and Engel 1980) along with the declining quality of current growth close to the plant base may be key mechanisms causing cattle avoidance of plant biomass below the level of the remaining litter following defoliation the previous fall. These findings therefore support the effects reported earlier in this section on the influence of remaining stubble height on subsequent grazing height and levels of utilization. Other investigators have also found that cattle preferred short, high quality plants over tall, low quality ones in order to maximize nutrient intake, even though taller plants offered more biomass per unit area (Wallis de Vries et al. 1999).

4.5 Conclusion

Results of this study generally indicate that the presence of greater amounts of standing litter served as a deterrent to the utilization of, but not necessarily the selection of, rough fescue plants by cattle. Some protection of current plant growth was achieved under moderate grazing. Maintaining a moderate level of standing litter within fescue grassland prior to the onset of spring growth appears to decrease the likelihood that rough fescue plants will receive heavy defoliation if subjected to light to moderate grazing pressure. On an average rough fescue plant (average fall leaf length of 39 cm), the spring height of standing litter would have to be approximately eight cm to protect the plant from overgrazing if the target level of utilization was ~40% (i.e. light to moderate grazing pressure).

Many researchers have determined that utilization of rough fescue during the critical growing season is detrimental to its vigor, survival, and productivity (Willms et al. 1985, McLean and Wikeem 1985). However, ranchers and resource managers are often restricted in their management options, necessitating the grazing of native rough fescue grassland during the critical spring period. McLean and Wikeem (1985) reported that clipping rough fescue earlier in the spring may have less impact on plant death, leaf height, tiller numbers and yield per plant than late spring grazing, a finding also reported by Bogen (2001).

Further study is required to investigate the most appropriate time of grazing during spring (i.e. relative to phenological development) as well as the maximum level of utilization in order to ensure the sustainability of rough fescue within the plant community. The results of this study may also be extrapolated to estimate an approximate minimum level of fescue stubble required in spring to help protect growing rough fescue plants from over-utilization.

4.6 *Literature Cited*

Bakker, J.P., J. deLeeuw, and S.E. Van Wieren. 1984. Micro-patterns in grassland vegetation created and sustained by sheep grazing. Vegetatio. 53:153-161.

Bogen, A.D. 2001. Foothills rough fescue response to fire and defoliation. M.SC. Thesis Univ. of Alberta. Edmonton, AB.

Canada Soil Inventory. 1989. Soil landscapes of Canada-Alberta. Land Resource Research Center, Research Branch, Agriculture Canada, Ottawa, Ont. Agric. Can. Publ. 5237/B. 22 pp 1:1 million scale map complied by LRRC Staff in Ottawa and Alberta.

Carr, D.E., and P.J. Lee. 2002. Post ANOVA comparison in SAS. http://toolkit.virginia.edu/cgi-local/tk/UVa_CLAS_2002_Spring_EVSC503-1/displaymaterials:lab5handout.doc/lab5handout.doc

Culley, M.J., R.S. Campbell, and R.H. Canfield. 1933. Values and limitations of clipped quadrats. Ecology. 14:35-39.

Dormaar, J.F., and W.D. Willms. 1990. Sustainable production from the rough fescue prairie. J. Soil Water Conserv. 45:137-140.

Ellison, L. 1960. Influence of grazing on plant succession of rangelands. Bot. Review. 26:1-78.

Entz, T. 2002. Personal communication. Statistician; Agriculture Canada Research Station, Lethbridge, AB.

Flores, E.R., E.A. Laca, T.C. Griggs, and M.W. Demment. 1993. Sward height and vertical morphological differentiation determine cattle bite dimensions. Agron. J. 85:527-532.

Ganskopp, D., and J. Rose. 1992. Bunchgrass basal area affects selection of plants by cattle. J. Range Manage. 45:538-541.

Ganskopp, D., R. Angell, and J. Rose. 1992. Response of cattle to cured reproductive stems in caespitose grass. J. Range Manage. 45:401-404.

Johnston, A. 1961. Comparison of lightly grazed and ungrazed range in the fescue grassland of southwestern Alberta. Can. J. Plant Sci. 41:615-622.

Laca, E.A., L.A. Shipley and E.D. Reid. 2001. Structural anti-quality characteristics of range and pasture plants. J. Range Manage. 54:413-419.

Langer, R.H.M. 1972. How grasses grow. The institute of Biology's. Studies in Biology no. 34. Edward Arnold Limited. London.

McLean, A., and S. Wikeem. 1985. Rough fescue response to season and intensity of defoliation. J. Range Manage. 38:-100-103.

Moss, E.H. 1944. The prairie and associated vegetation of southwestern Alberta. Can. J. Research. C. 22:218-229.

Moss, E.H., and J.A. Campbell. 1947. The fescue grasslands of Alberta. Can. J. Res. Sect. C. Bot. Sci. 25:209-227.

Naeth M.A., A.W. Bailey, D.J. Pluth, D.S. Chanasyk, and R.T. Hardin. 1991. Grazing impacts on litter and soil organic matter in mixed prairie and fescue grassland ecosystems of Alberta. J. Range Manage. 44:7-12.

O'Reagain, P.J., and E.A. Grau. 1995. Sequence of species selection by cattle and sheep on South African sourveld. J. Range Manage. 48:314-321.

O'Reagain, P.J., and E.A. Grau. 1995. Sequence of species selection by cattle and sheep on South African sourveld. J. Range Manage. 48:314-321.

Pfeiffer, K.E. and D.C. Hartnett. 1995. Bison selectivity and grazing response of little bluestem in tallgrass prairie. J. Range Manage. 48:26-31.

Romo, J.T., Tremblay, M.E., and D. Barber. 1997. Are there economic benefits of accessing forage in wolf plants of crested wheat grass? Can. J. Plant Sci. 77:367-371.

SAS. 1999-2000. Release 8.1 SAS Institute Inc., Cary, NC.

Sinton, H.M. 1980. Effect of burning and mowing on *Festuca hallii*. M.Sc. Thesis University of Alberta. Edmonton, Alberta.

Sinton-Gerling, H., A.W. Bailey, and W.D. Willms. 1995. The effects of burning on *Festuca hallii* in parklands of central Alberta. Can. J. Bot. 73:937-942.

Spedding, C. R. W. 1971. Grassland Ecology. Oxford Univ. Press, Ely House, London.

Steel, R.G.D., J.H. Torrie, and D.A. Dickey. 1997. Principles and Procedures of Statistics: a biometrical approach, 3rd edition. McGraw-Hill, New York.

Strong, W.L., and K.R. Legget. 1992. Ecoregions of Alberta: Volume 1. Alberta Forestry, Lands, and Wildlife, Land Info. Services, Edmonton

Van Soest, P. J., J. B. Robertson, and B. A. Lewis. 1991. Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci. 74:3583-3597.

Wallis de Vries, M.F., E.A. Laca, and M.W. Demment. 1999. The importance of scale of patchiness for selectivity in grazing herbivores. Oecologia. 121:355-363.

Willms, W.D. 1988a. Response of rough fescue (*Festuca scabrella*) to light, water, temperature, and litter removal, under controlled conditions. Can. J. Bot. 66:429-434.

Willms, W.D. and J. Fraser. 1992. Growth characteristics of rough fescue (*Festuca scabrella* var. *campestris*) after 3 years of repeated harvesting at scheduled frequencies and heights. Can. J. Bot. 70:2125-2129.

Willms, W.D., A.W. Bailey, A. McLean, and C. Kalnin. 1981. Effects of fall clipping or burning on the distribution of chemical constituents in bluebunch wheatgrass in spring. J. Range Manag. 34:267-269.

Willms, W.D., A.W. Bailey, and A. McLean. 1980. Effect of clipping or burning on some morphological characteristics of *Agropyron spicatum*. Can. J. Bot. 58:2309-2312.

Willms, W.D., and L.M. Rode. 1998. Forage selection by cattle on fescue prairie in summer or winter. J. Range Manage. 51:496-500.

Willms, W.D., B.W. Adams, and J.F. Dormaar. 1996. Seasonal changes of herbage biomass on the fescue prairie. J. Range Manage. 49:100-104.

Willms, W.D., J.F. Dormaar and G.B. Schaalje. 1988. Stability of grazed patches on rough fescue grasslands. J. Range Manage. 41:503-508.

Willms, W.D., S. Smoliak, and J.F. Dormaar. 1985. Effects of stocking rate on rough fescue grassland vegetation. J. Range Manage. 38:220-225.

Wroe, R.A., S. Smoliak, B.W. Adams, W.D. Willms, and M.L. Anderson. 1988. Guide to range condition and stocking rates for Alberta grasslands. Publ. of Alberta Forestry, Lands, and Wildlife, Edmonton, Alberta.

Zar, J.H. 1999. Biostatistical Analysis, 4th ed. Prentice-Hall, Inc. Upper Saddle River, NJ.

Table 4.1 **Ocular estimates of production (uncorrected) and percent cover of species at the Stavely Agriculture and Agri-Food Canada sub-station grazing pastures.**

	Pasture A [1]		Pasture B [1]		Pasture C [2]		Average	
Species [3]	**g/m²**	**%cov/m²**	**g/m²**	**%cov/m²**	**g/m²**	**%cov/m²**	**g/m²**	**%cov/m²**
Poa prat	31.65	36.66	11.91	17.44	22.99	27.25	22.2	27.9
Fest cam	23.47	10.63	27.59	15.65	30.50	18.31	27.2	14.1
Dant par	13.78	16.58	11.61	8.94	11.34	12.81	12.2	12.8
Brom ine	11.83	4.42	7	3.68	9.37	10.98	9.4	6.4
Astelae	-	-	-	-	9.93	4.69	3.3	1.6
Gali bor	-	-	-	-	-	0.73	-	0.2
Geum tri	3.00	0.50	11.55	-	1.41	-	5.3	0.2
Fest ida	3.16	1.02	3.20	-	1.99	1.69	2.8	0.9
Rosa	-	-	-	-	6.39	-	2.1	-
Lath occ	-	-	-	-	-	0.37	-	0.1
Pote fru	-	1.61	-	-	-	-	-	0.5
Agro das	3.00	1.53	-	-	-	-	1.0	0.5
Brom pum	-	-	-	-	2.00	1.01	0.7	0.3
Mona fis	-	-	-	-	-	1.00	-	0.3
Agro uni	-	0.51	-	-	-	-	-	0.2
Carex	-	0.40	-	-	-	-	-	0.1
Agos gla	5.19	-	-	-	-	-	1.7	-
Dote con	8.35	-	5.89	-	-	-	4.7	-
Ante ana	2.35	-	2.95	-	-	-	1.8	-
Antenn	-	-	2.70	-	-	-	0.9	-
Aster	-	-	3.40	-	1.33	-	1.6	-

[1] Estimates made in Spring 2000 and/or Spring 2001.

[2] Estimates made in Fall 2000 and Fall 2001.

[3] Species named by 7 letter codes. The first 4 are from the genus name, the last 3 are from the species name. Species with 6 or fewer letters are identified to the genus level only and the coded by genus name.

Table 4.2 Summary of the various time-lines of the study in growing, grazing, measurement, and treatment days.

Time-line	May 28	May 29	May 30	May 31	Jun 1	Jun 2	Jun 3	Jun 4	Jun 5	Jun 6
Growing	0	1	2	3	4	5	6	7	8	9
Grazing	0	0.5	1.5	2.5	3.5	4.5	5.5	6	0	0
Measurement	initial	-	-	1	2	-	3	4	-	5
Treatment	-	start	-	-	mid	-	-	end	-	-

Table 4.3 Least square means of *Festuca campestris* plant basal area among the 3 study pastures (n=40/pasture).

Cell	**Basal Area[1] (cm^2)** **LSmean**
A	303.0 a[2]
B	359.9 b
C	351.6 b
stderr	13.8

[1] Measurements taken 7 to 9, November 2000.

[2] Within a column, means followed by different letters differ significantly (Tukey; $p<0.05$).

Table 4.4 Least square means of *Festuca campestris* spring growth (i.e. initial, or pre-grazing) as represented by mean height and canopy volume on 28 May, 2001, following four clipping treatments applied the previous fall.

Grazing Pasture	Treatment[1]	Initial Height (cm) LSmean	Initial Volume (cm^3) LSmean
	Pr>F/R^2	<0.0001/0.67	<0.01/0.53
	Control	30 a[2]	8673 a
A	14	30 a	8808 a
(n=39)	7	28 a	9172 a
	2.5	22 b	6259 b
	stderr	0.97	605
	Pr>F/R^2	0.02/0.46	<0.001/0.63
	Control	30 a	12510 a
B	14	26 ab	8044 b
(n=40)	7	25 b	8441 b
	2.5	25 b	9014 b
	stderr	1.08	686
	Pr>F/R^2	<0.001/0.62	0.04/0.43
	Control	29 a	10110 ab
C	14	28 a	9605 ab
(n=40)	7	29 a	11081 a
	2.5	23 b	7645 b
	stderr	0.9	800

[1] Treatments applied November 7 to 9, 2000 and included: (1) control (no standing litter removal); (2) litter removal above 14 cm (leaving 14cm of litter on and around the base of the plant); (3) litter removal above 7 cm; and (4) litter removal above 2.5 cm.

[2] Within a grazing pasture and column, means followed by different letters differ significantly (Tukey; p<0.05).

Table 4.5 Mean plant height and height growth of ungrazed *Festuca campestris* plants (n=40) in May 2001, after four different litter removal treatments applied the previous fall.

Clip	--------Height (cm)--------				--Cumulative Growth (cm)--		
Treatment[1]	Initial	Day 4	Day 7	Day 9	to Day 4	to Day 7	to Day 9
Control	29 a[2]	30 a	32 a	34 a	1 a	3 a	4 a
14 cm	28 a	30 a	32 a	33 a	2 a	3 a	5 a
7 cm	29 a	30 a	32 a	33 a	1 a	3 a	4 a
2.5 cm	23 b	25 b	26 b	26 b	1 a	3 a	3 a
stderr	0.98	1.1	1.1	1.2	0.4	0.5	0.6
Grand Means	-	-	-	-	1	3	4

[1] Treatments applied 7-9 November, 2000 and included: (1) control (no standing litter removal); (2) litter removal above 14 cm (leaving 14cm of litter on and around the base of the plant); (3) litter removal above 7 cm; and (4) litter removal above 2.5 cm.

[2] Within a column, means followed by different letters differ significantly (Tukey; $p<0.05$).

Table 4.6 Least square means for *Festuca campestris* biomass production on 6 June, 2001, following standing litter removal above four different heights applied the preceding fall at Stavely, AB.

Treatment	LSmean Biomass Production (g)
Control	30.0 a[1]
14 cm	22.6 a
7 cm	25.7 a
2.5 cm	17.4 a
stderr	2.97

[1] Within a column, treatment means followed by different letters differ significantly (Tukey; $p<0.05$). Treatment sample size equals ten.

Table 4.7 Accumulative count of *Festuca campestris* plants selected during a six-day spring grazing trial following standing litter removal at four different stubble heights applied the preceding fall at Stavely, AB.

Treatment[1]	May 31	Jun 1[2]	Jun 3	Jun 4[2]
control (n=20)	10 a[3]	15 a	17 a	17 a
14 (n=20)	19 b	20 b	20 a	20 a
7 (n=20)	20 b	20 b	20 a	20 a
2.5 (n=19)	17 b	18 ab	19 a	19 a

[1] Treatments applied November 7 to 9, 2000 and included: (1) control (no standing litter removal); (2) litter removal above 14 cm (leaving 14 cm of litter on and around the base of the plant); (3) litter removal above 7 cm; and (4) litter removal above 2.5 cm.

[2] June 1 and 4 represent the middle and last day of the grazing period.

[3] Results of pair-wise treatment comparisons. Within a column, treatments followed by different letters are significantly different ($p<0.05$; Fisher).

Table 4.8 Arithmetic least square means of *Festuca campestris* biomass utilization (percent plant removed) during the first week of June, 2001, within different clipping treatments applied the preceding fall.

Grazing Pasture	Treatment[1]	May 31	Jun 1 [2]	Jun 3	Jun 4 [2]
A (n=39)	Control (n=10)	5 a[3]	7 a	9 a	8 a
	14 cm (n=10)	14 ab	19 ab	22 b	22 b
	7 cm (n=10)	30 b	33 b	40 c	40 c
	2.5 cm (n=9)	36 b*	43 b*	59 d	60 d
	stderr	(n=10) 5.4 (n=9) 5.8	(n=10) 5.3 (n=9) 5.7	(n=10) 3.7 (n=9) 4.0	(n=10) 3.5 (n=9) 3.7
B (n=40)	Control	6 a	7 a	9 a	10 a
	14 cm	20 b	22 b	21 b	20 b
	7 cm	42 c	43 c	44 c	43 c
	2.5 cm	68 d*	68 d*	69 d	68 d
	stderr	2.4	2.1	1.8	2

[1] Treatments applied 7 to 9 November 2000 and included: (1) control (no standing litter removal); (2) litter removal above 14 cm (leaving 14 cm of litter on and around the base of the plant); (3) litter removal above 7 cm; and (4) litter removal above 2.5 cm.

[2] June 1 and 4 represent the middle and last day of the grazing period. Decreases in utilization over time are a result of plant growth.

[3] Significance tested and reported from arcsin transformed values. Within a grazing pasture and column, means followed by different letters differ significantly ($p<0.05$; Tukey). Within a column and treatment, means followed by an asterisk are significantly different ($p<0.05$; Tukey).

Table 4.9 Least square means of *Festuca campestris* ADF content (%) in different height segments of ungrazed plants subjected to four different litter removal treatments and harvested 6 June, 2001 at Stavely, AB.

Component	Clipping Treatment[2]	Segment[1]	LSM	n	Stderr
Litter	Control	1	45.97a[3]	10	0.43
		2	45.30a	10	0.34
		3,4 and 5	44.62a	9	0.7
Current Growth	Control	1	36.77a	10	0.53
		2	35.90b		0.66
		3	32.43c		0.78
		4 and 5	28.42d		0.71
	14 cm	1	37.89a	10	0.64
		2	36.18b		0.76
		3	33.79c		0.98
		4 and 5	28.48d		0.72
	7 cm	1	36.56a	10	0.47
		2	35.35b		0.51
		3	31.64c		0.63
		4 and 5	27.83d		0.87
	2.5 cm	1	36.42a	10	0.35
		2	34.81b		0.51
		3	31.90c		0.47
		4 and 5	28.85d		0.49

[1] Segments are numbered starting at the plant base. Upper segments were pooled to obtain sufficient sample material. Each segment represents one quartile (i.e. 20%) of a plant height and are not cumulative.

[2] Treatments applied 7-9 November, 2000 and included: (1) control (no standing dead litter removal); (2) litter removal above 14 cm (leaving 14cm of litter on and around the base of the plant); (3) litter removal above 7 cm; and (4) litter removal above 2.5 cm.

[3] Within a component and column, means followed by different letters differ significantly (p<0.05; Tukey).

Table 4.10 Percent crude protein least square means of *Festuca campestris* segments of ungrazed plants harvested 6 June, 2001 at Stavely, AB.

Component	Clipping Treatment[2]	Segment[1]	LSMean	n	Stderr
Litter	Control	1	5.84a[3]	10	0.37
		2	5.33a	10	0.27
		3,4 and 5	5.60a	9	0.38
Current Growth	Combined	1	8.96a	40	0.16
		2	11.30b		0.23
		3	13.32c		0.22
		4 and 5	14.64d		0.27

[1] Segments are numbered starting at the plant base. Upper segments were pooled to obtain sufficient sample material. Each segment represents one quartile (i.e. 20%) of a plant height and are not cumulative.

[2] Only control was analyzed for litter component. No significant difference existed among treatments (p=0.10) for current growth. Treatments were applied 7-9 of November, 2000 and included: (1) control (no standinglitter removal); (2) litter removal above 14 cm (leaving 14cm of litter on and around the base of the plant); (3) litter removal above 7 cm; and (4) litter removal above 2.5 cm.

[3] Within a treatment and column, means followed by different letters differ significantly ($p<0.05$; Tukey).

Figure 4.1 Precipitation for the Agriculture and Agri-Food Canada sub-station near Stavely, AB.

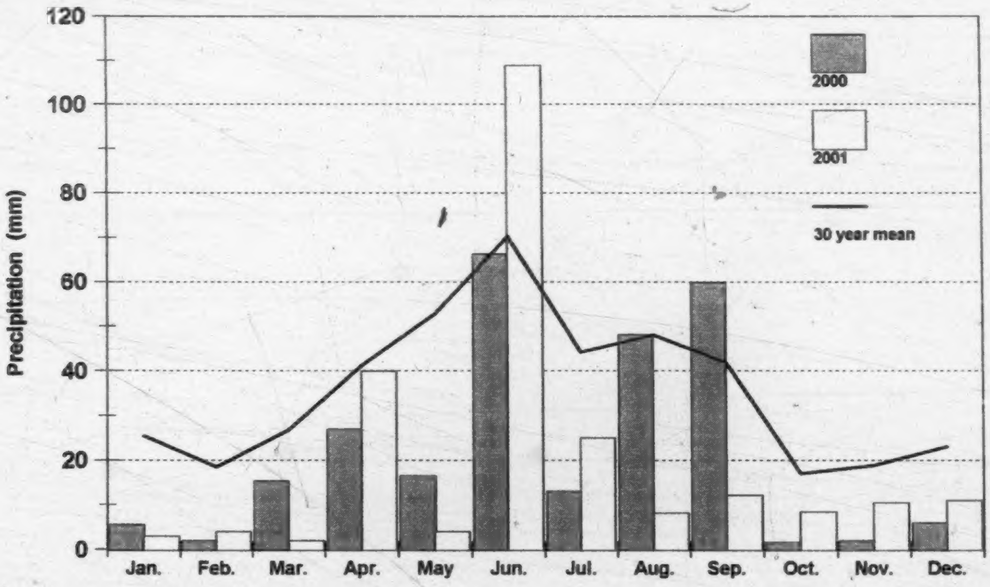


Figure 4.2 Temperatures for the Agriculture and Agri-Food Canada sub-station near Stavely, AB.

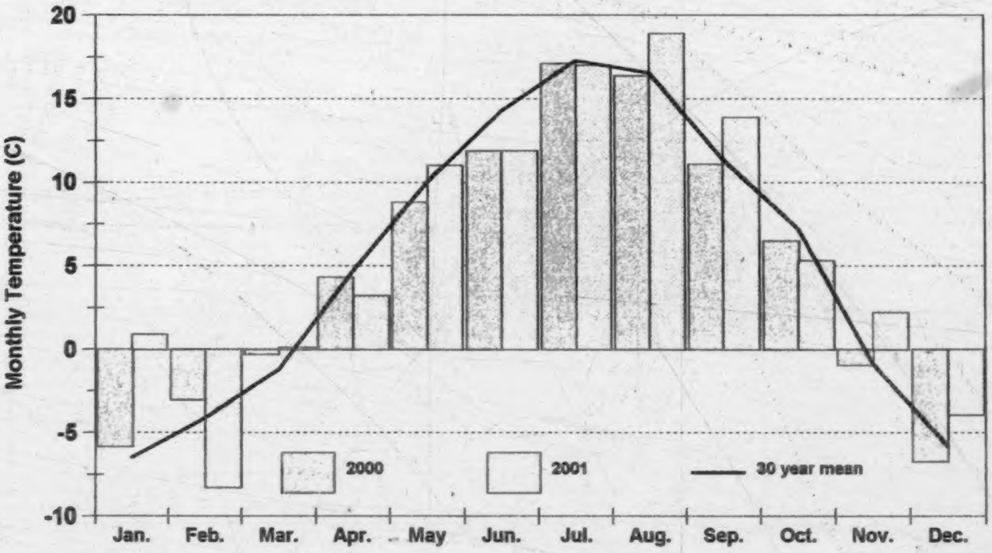


Figure 4.3 Location of rough fescue plants selected in 2 belt transects in spring grazed pastures and control plants in an ungrazed pasture.

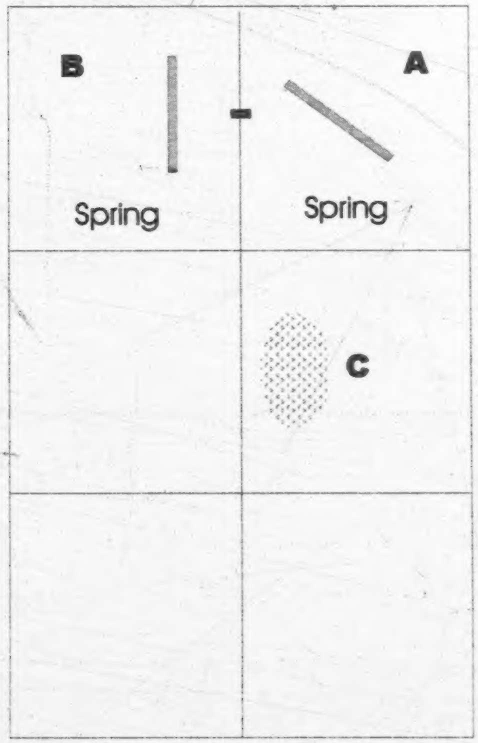

B
A
Spring
Spring
C

Figure 4.4 Analysis of utilization flow chart (section 4.3.1).

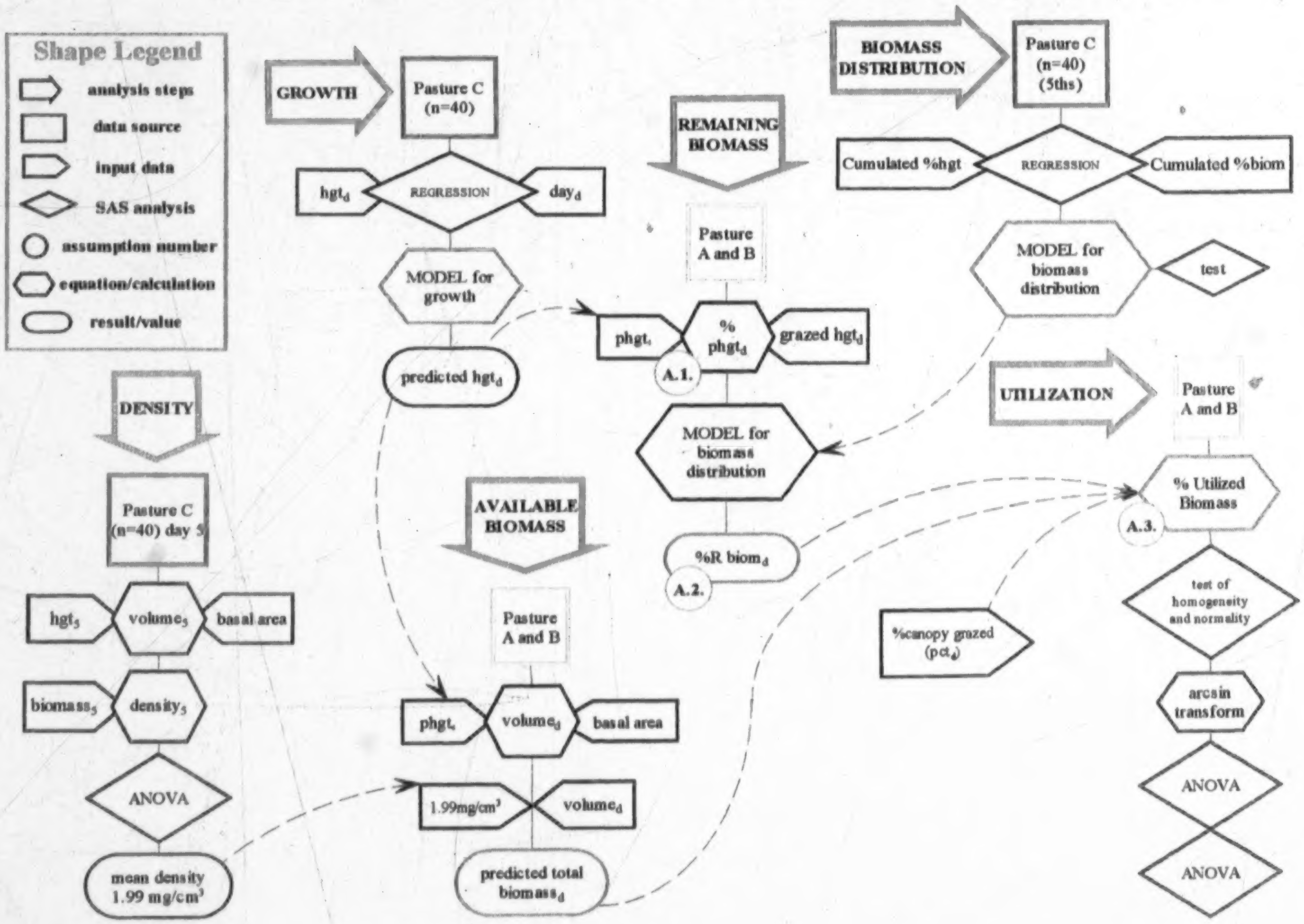
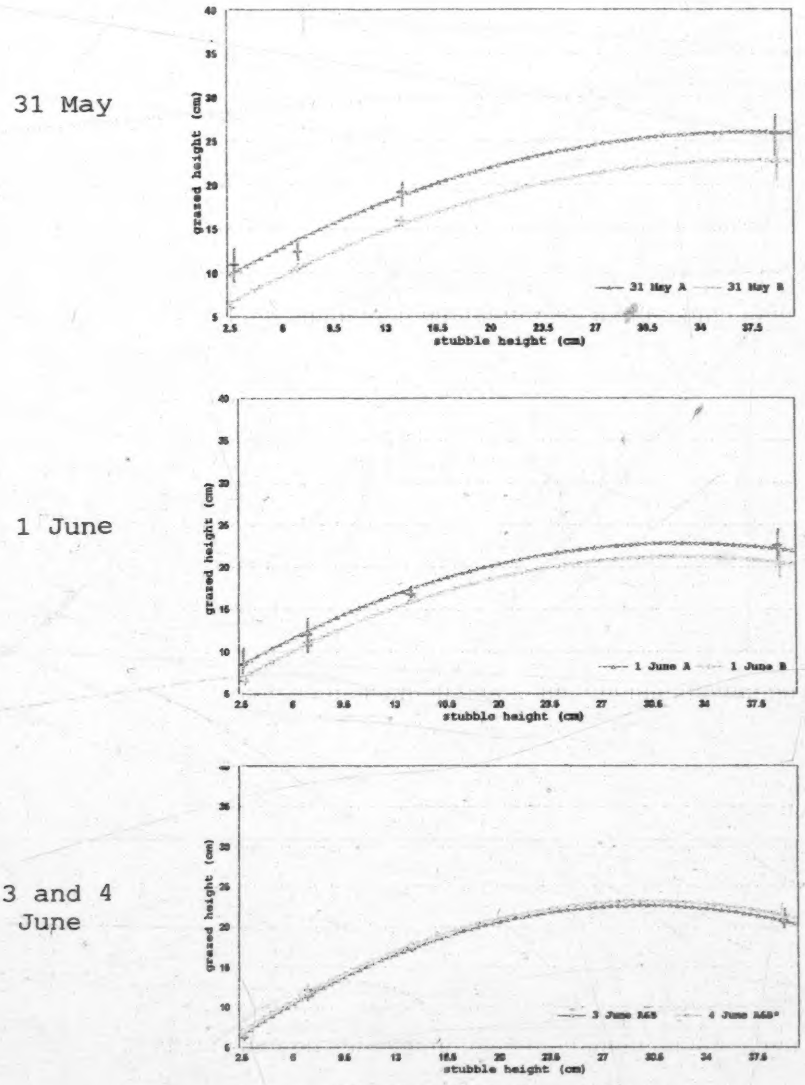

Shape Legend
analysis steps
data source
input data
SAS analysis
assumption number
equation/calculation
result/value
GROWTH
Pasture C (n=40)
hgt$_d$
REGRESSION
day$_d$
MODEL for growth
predicted hgt$_d$
REMAINING BIOMASS
Pasture A and B
phgt$_t$
% phgt$_d$
grazed hgt$_d$
A.1.
MODEL for biomass distribution
%R biom$_d$
A.2.
BIOMASS DISTRIBUTION
Pasture C (n=40) (5ths)
Cumulated %hgt
REGRESSION
Cumulated %biom
MODEL for biomass distribution
test
UTILIZATION
Pasture A and B
% Utilized Biomass
A.3.
%canopy grazed (pct$_d$)
test of homogeneity and normality
arcsin transform
ANOVA
ANOVA
DENSITY
Pasture C (n=40) day 5
hgt$_5$
volume$_5$
basal area
biomass$_5$
density$_5$
ANOVA
mean density 1.99 mg/cm^3
AVAILABLE BIOMASS
Pasture A and B
phgt$_t$
volume$_d$
basal area
1.99mg/cm^3
volume$_d$
predicted total biomass$_d$

Figure 4.5 Relationship between initial rough fescue stubble height and subsequent grazing height for 4 days of measurement during a 6 day grazing period from 29 May to 4 June 2001, in pastures A and B near Stavely, AB.* (n=39 in pasture A; n=40 in pasture B)



* On 3 June and 4 June, the relationship did not differ among grazing cells.

5 Synthesis

Two key factors strongly influencing rangeland health, including the abundance of important forage species, are plant selection and utilization by cattle. Overuse of individual preferred plant species gives competitive advantage to lesser used neighbours and is a key mechanism responsible for a shift in species composition within grasslands (Ellison 1960, Johnston 1961, Looman 1969, McLean and Wikeem 1985, Willms et al. 1985, Willms 1991, Willms et al. 1996).

In native rough fescue (*Festuca campestris* Rydb.) rangeland, heavy grazing pressure on rough fescue, particularly during spring or summer, will to lead to changes in species composition in favour of more grazing resistant, often invasive species, such as Kentucky bluegrass (*Poa pratensis,* L.) (Willms et al. 1985, Willms et al. 1996). Even native range in good or excellent condition often has small areas that have been invaded to varying degrees (Willms et al. 1988). Invaded grasslands generally are considered to be in reduced condition or health (Willms et al. 1996). Kentucky bluegrass dominated, communities are less productive and suffer greater weathering losses (Willms et al. 1996). They also have reduced native species diversity and are less resistant to drought conditions compared to native dominated communities (Willms et al. 1996, Beaty and Engel 1980, Moisey and Adams, 2001).

As a result, managers are seeking practical grazing strategies to reduce the competitiveness of invasive plants while achieving effective but sustainable utilization of native forages, including rough fescue. Some producers are experimenting with a system known as skim grazing (Thomas 2001, Adams, 2001). Under this system, managers apply spring grazing at light stocking rates in an attempt to utilise rapidly growing "soft" invasive grasses, and then return later in the season to graze the remaining forage. "Soft" grasses (e.g. Kentucky bluegrass and smooth brome) are those that have relatively less crude fibre, are more susceptible to weathering, have greater regrowth potential but lower overall annual productivity in a rangeland setting, and shallower root systems (Walton 1983) compared to "hard" grasses (e.g. rough fescue and Parry oat grass [*Danthonia parryi* Scribn.]) (Willms et al. 1996).

Deliberate selection of invasive species by cattle under skim grazing would accomplish several objectives, including (1) conserving rough fescue within the stand, (2) reducing the competitiveness of invasive species in the sward, and (3) maintaining the invasive species in a vegetative state, thereby potentially increasing their forage quality later in the summer. Alternatively, if there is no preference or a preference for native species like rough fescue during the spring, the practice of skim grazing could be harmful to the long-term production and sustainability of fescue grasslands.

Though apparently sound in theory, little research has addressed whether skim grazing is able to influence plant selection by grazing cattle. Moreover, little information exists on the seasonal preference of cattle for different forage plants, including soft and hard grasses, within areas such as the fescue prairie. Two studies were conducted at the Agriculture Canada research sub-station near Stavely, Alberta to determine if cattle preference was affected by season of use or standing litter.

The first study examined preferences by cattle for four individual plant species in a native sward (Section 3). This experiment was conducted over two years and tested the hypothesis that cattle have no seasonal preference for dominant invasive species or native species.

Preferences were detected among the four species studied. In the spring of either year, rough fescue was given the greatest numerical preference rating (PR) but it was not significantly different from that of Kentucky bluegrass. Rough fescue was significantly different from Parry oat grass and smooth brome (*Bromus inermis,* Leyss.) which were avoided.

Were preferences related to the season of grazing? The results also indicate that Kentucky bluegrass received a greater PR in the fall and fall regrowth treatments than in the spring treatment. In the spring, rough fescue was preferred but in the fall grazing treatments it was avoided.

The observed cattle's lack of avoidance of rough fescue in the spring is contrary to what was expected based on the use of skim-grazing practices (i.e. that cattle would select invasive soft grasses over native, hard grasses). The spring PR of rough fescue and Kentucky bluegrass suggests that cattle utilize both these species approximately equal to their availability in the stand. Moreover, the observed non-avoidance of rough fescue indicates the practice of skim grazing during spring, particularly at excessive stocking rates, may negatively impact the long-term sustainability of fescue grassland. Continued selection and utilization of actively growing rough fescue will cause its eventual reduction in the plant community and allow the increase of more grazing resistant species, including Kentucky bluegrass.

In contrast, fall and fall regrowth grazing appears to be a practice conducive to the conservation of fescue grasslands while taking advantage of the forage production of un-senesced invasive species like Kentucky bluegrass. Increases in cattle PR for rough fescue from the middle to the end of the grazing period (i.e. over time), in the fall and fall regrowth grazed pastures, may be an indication of a change in foraging patterns. It is possible that as the availability of more 'succulent' bluegrass patches declined, cattle switched to alternative forage species in order to sustain nutrient intake (Emlen 1966).

Forage preferences are influenced by a number of factors (Laca 1998, Allen and Segarra 2001, Willms et al. 1988, Hein and Miller 1992, Allison 1985, Thornton and Minson 1973, Burritt et al. 2000, Heady 1964 and Owens et al. 1991). The current study obviously did not consider the effects of all other factors (e.g. stocking rate, range condition, etc) which may also influence cattle preference for a plant species. Other experimental approaches, examining different factors, are required to determine if the preference observations reported here are consistent under a variety of conditions.

The second research project investigated the impact of various amounts of standing litter (e.g. carryover) on subsequent rough fescue selection and utilization by cattle (section 4). The hypothesis tested was that increased retention of standing litter in the fall would reduce the extent of subsequent spring utilization of rough fescue, by acting as a greater physical barrier to grazing animals.

Analysis of plant selection data after two days of spring grazing indicated that selection of undefoliated fescue plants was significantly less frequent than in any other defoliation treatment. However, by the end of the six-day trial plants of all treatments were selected similarly. Of all the plants examined, 96% were selected and utilized to some extent. Only 18% and 48% of plants were observed to be regrazed by cattle after three and six days, respectively. Clipping treatment alone had no significant effect on whether a plant was regrazed.

Biomass utilization increased as the amount of litter removal increased with previous defoliation. By the end of the grazing period, utilization was 63% on the most severe litter removal treatment (i.e. to 2.5 cm) compared to only 9% on the unclipped control.

The presence of greater amounts of standing litter apparently served as a deterrent to the degree of cattle use, but not the selection, of rough fescue plants by cattle, thereby protecting some of the current plant growth in this six-day grazing trial. Maintaining a moderate level of standing litter within fescue prior to the onset of spring growth appears to decrease the likelihood that rough fescue plants will receive heavy defoliation if subjected to light to moderate grazing pressure the following year.

In summary, skim grazing in the spring can potentially be detrimental to the long-term sustainability of rough fescue grasslands. However, managers may limit the spring utilization of rough fescue by maintaining adequate levels of standing litter thereby protecting the actively growing plant.

The writer's interpretation of the Bogen (2001), Sinton-Gerling et al. (1994), Willms and Fraser (1992), Willms (1991), and McLean and Wikeem (1985) studies was that managers may be able to graze livestock more frequently and more heavily (within limits) for one year without jeopardizing the longer term yields of fescue grasslands. Furthermore, sustained pressure at these theorized limited levels for even two years could have a stabilized but detrimental effect on the viability of rough fescue. These studies together with the findings of the current study, suggest that commonly used rotation or rest rotation grazing systems may be best suited to the management goals of maintaining sustainable, productive, and healthy fescue grasslands.

More research is required to determine the effective combination of phenological timing and intensity of spring defoliation on rough fescue without causing unacceptable damage to its vigor, production and survival within the plant community. Coughenour (1991) suggests that the landscape scale (i.e. plant community) of plant responses to herbivory could not be assumed to be equal to the plant scale. For example, results of grazing the sward at a uniform 50% utilization could be very different from the results of grazing 50% of the plants at 100% utilization. Indeed, it was unlikely that any plant would be grazed in an "average" way if there were varying plant communities or favoured patches present. Therefore any initiated study should not only be conducted over a number of years, but the associated effects within the plant community (e.g. species composition) should be tracked simultaneously to further qualify any findings specific to individual rough fescue plant responses to defoliation.

5.1 Literature Cited

Adams, B.A. 2001. Regional Range Management Specialist. Southeast Region, Alberta Sustainable Resource Development. Personal Communication.

Allen, V.G., and E. Segarra. 2001. Anti-quality components in forage: Overview, significance and economic impact 1. J. Range Manage. 54:409-412.

Allison, C.D. 1985. Factors affecting forage intake by range ruminants: A review. J. Range Manage. 38:305-311.

Beaty, E.R. and J.L. Engel. 1980. Forage quality measurements and forage research. A review, critique and interpretation. J. Range Manage. 33:49-54.

Burritt, E.A., R.E. Banner, and F.D. Provenza. 2000. Sagebrush ingestion by lambs: Effect of experience and macronurients. J. Range Manage. 53:91-96.

Coughenour, M.B. 1991. Spatial components of plant-herbivore interactions in pastoral, ranching and native ungulate ecosystems. J. Range Manage. 44:530-539.

Ellison, L. 1960. Influence of grazing on plant succession of rangelands. Bot. Review. 26:1-75.

Emlen, J.M. 1966. The role of time and energy in food preference. Amer. Natur. 100:611-617.

Heady, H.F. 1964. Palatability of herbage and animal preference. J. Range Manage. 17:76-82.

Hein, D.G., and S.D. Miller. 1992. Influence of leafy spurge on forage utilization by cattle. J. Range Manage. 45:405-407.

Johnston, A. 1961. Comparison of lightly grazed and ungrazed range in the fescue grassland of southwestern Alberta. Can. J. Plant Sci. 41:615-622.

Laca, E.A. 1998. Spatial memory and food searching mechanisms of cattle. J. Range Manage. 51:370-378.

Looman, J. 1969. The fescue grassland of western Canada. Vegetatio. 19:128-145.

McLean, A., and S. Wikeem. 1985. Rough fescue response to season and intensity of defoliation. J. Range Manage. 38:-100-103.

Owens, M.K., K. L. Launchbaugh, and J.W. Halloway. 1991. Pasture characteristics affecting spatial distribution of utilization by cattle in mixed brush communities. J. Range Manage. 44:118-123.

Sinton-Gerling, H., A.W. Bailey, and W.D. Willms. 1995. The effects of burning on *Festuca hallii* in parklands of central Alberta. Can. J. Bot. 73:937-942.

Thomas, L. 2001. "Skim" grazing helps get this ranch ready for drought. Canadian Cattlemen. June/July:8-9.

Thornton, R.F., and D.J. Minson. 1973. The relationship between apparent retention time in the rumen, voluntary intake, and apparent digestibility of legume and grass diets in sheep. Aust. J. Agr. Res. 24:889-898.

Walton, P.D. 1983. Production and management of cultivated forages. Reston Publishing Company, Inc. Reston, Virginia.

Willms, W.D. 1991. Cutting frequency and cutting height effects on rough fescue and Parry oat grass yields. J. Range Manage. 44:82-86.

Willms, W.D. and J. Fraser. 1992. Growth characteristics of rough fescue (*Festuca scabrella* var. *campestris*) after 3 years of repeated harvesting at scheduled frequencies and heights. Can. J. Bot. 70:2125-2129.

Willms, W.D., B.W. Adams, and J.F. Dormaar. 1996. Seasonal changes of herbage biomass on the fescue prairie. J. Range Manage. 49:100-104.

Willms, W.D., J.F. Dormaar and G.B. Schaalje. 1988. Stability of grazed patches on rough fescue grasslands. J. Range Manage. 41:503-508.

Willms, W.D., S. Smoliak, and J.F. Dormaar. 1985. Effects of stocking rate on rough fescue grassland vegetation. J. Range Manage. 38:220-225.

6 APPENDIX

Figure A.1 The relationship of visually estimated *Festuca campestris* biomass to clipped (actual) biomass.

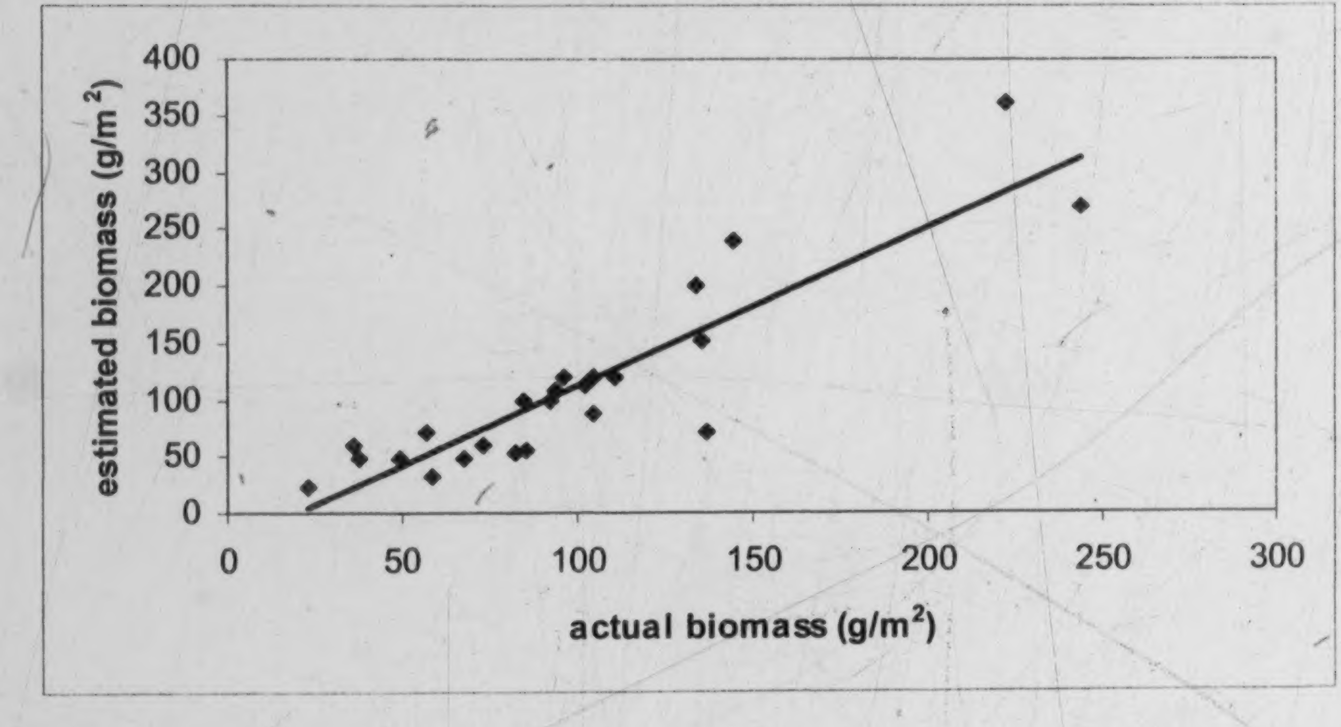


Figure A.2 Height-biomass distribution model of *Poa pratensis* plants collected 10 October 2001.

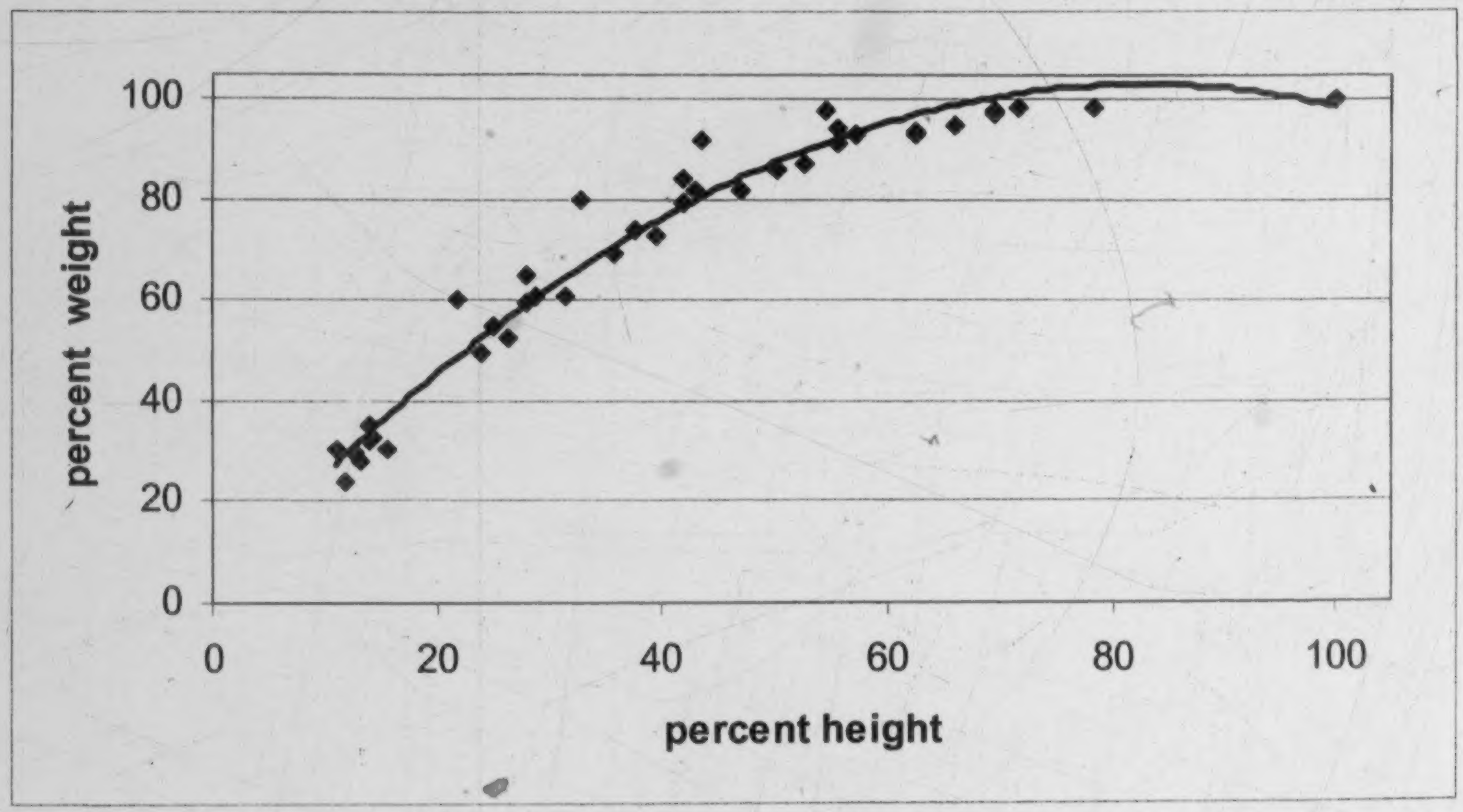


Table A.1 Estimates of total biomass utilized (DM grams) and the proportion of total biomass available utilized (%) for four species within fescue grasslands by season and year of sampling at the Stavely Agriculture and Agri-Food Canada sub-station.[1]

Grazing Treatment	Species	2000		2001	
		(g)	%	(g)	%
Spring	*Bromus inermis*	11	9	12	9
	Danthonia parryii	28	23	6	3
	Festuca campestris	60	49	81	36
	Poa pratensis	24	20	127	56
	Total	123 (n=39 m^2)		197 (n=70 m^2)	
Fall	*Bromus inermis*	0	0	<1	<1
	Danthonia parryii	0	0	<1	<1
	Festuca campestris	31	28	5	4
	Poa pratensis	81	72	107	95
	Total	111 (n=30 m^2)		113 (n=36 m^2)	
Fall Regrowth	*Bromus inermis*	53	15	0	0
	Danthonia parryii	12	3	0	0
	Festuca campestris	55	16	3	2
	Poa pratensis	229	66	199	98
	Total	349 (n=30 m^2)		203 (n=34 m^2)	

[1] Total utilization estimates were summed from sampling plots (m^2) of pastures with the same grazing treatment.

Figure A.3 *Festuca campestris* growth from 28 May to 6 June 2001.

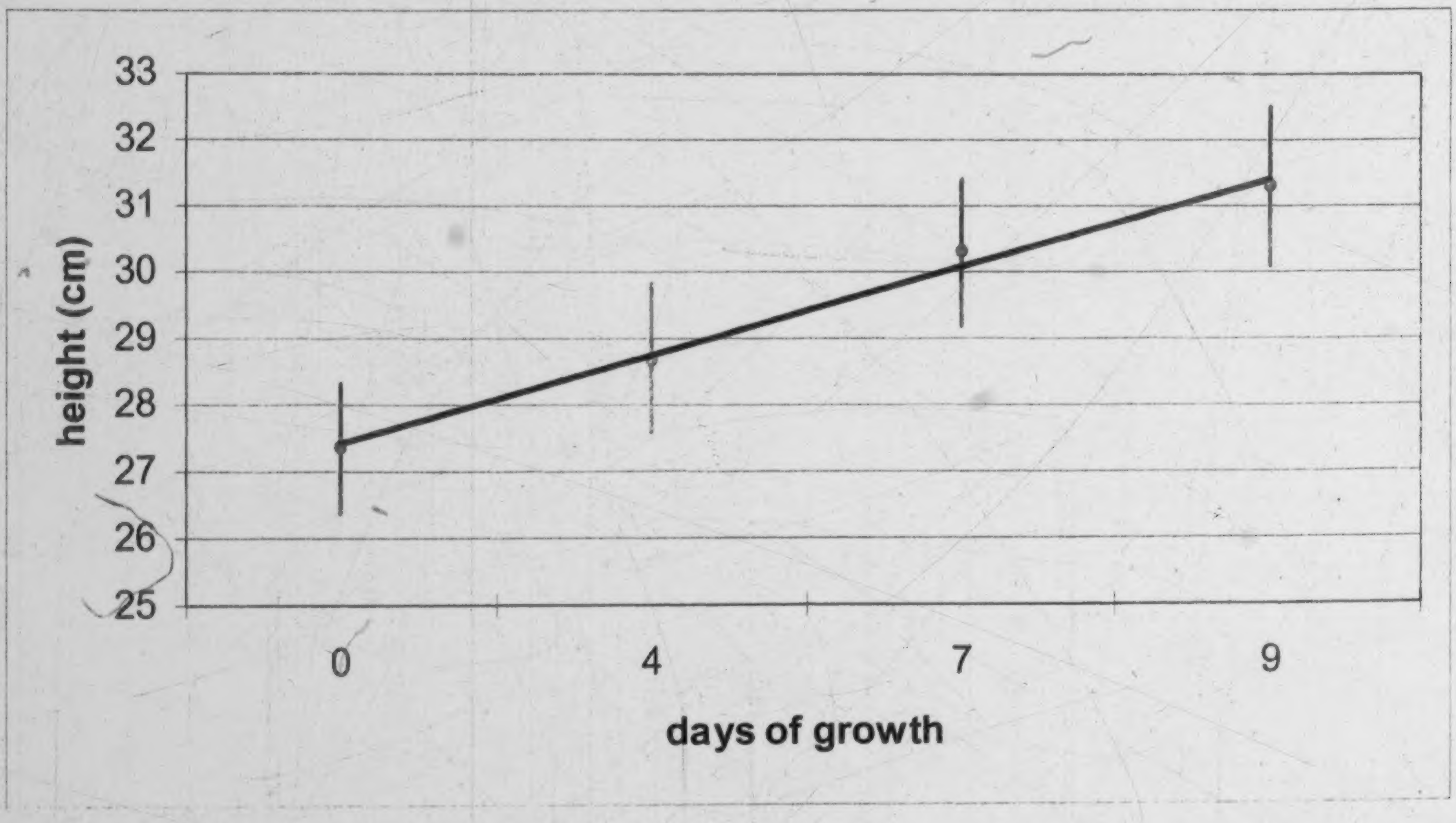


Figure A.4 Height-biomass distribution model of *Festuca campestris* plants collected 6 June 2001.